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Abstract

This paper investigates episodes of real exchange rate appreciations and depreciations for a sample of 85 countries, from 1960 to 1998. The equilibrium real exchange rate series are constructed by estimating cointegration vectors with fundamentals, and departures from it are obtained. A Markov Switching Model is used to characterize the misalignments series as stochastic autoregressive processes governed by two states corresponding to different means and variances. Three are the main findings: first, some countries present no evidence of distinct regimes for misalignment; second, for some countries, there is no RER misalignment in one the regimes; and, third, for those countries with two misalignment regimes, the appreciated regime have higher persistence than the depreciated one.

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1. Introduction

The purchasing power parity (PPP) hypothesis, in its original formulation, states that the price levels of two countries should be equal when measured in the same currency. It is an old idea in economics, but the expression was coined only in 1918 by Gustav Cassel. As Cassel (1918) puts it, "(a)s long as anything like free movement of merchandise and a somewhat comprehensive trade between the two countries takes place, the actual rate of exchange cannot deviate very much from this purchasing power parity [which is defined as the ratio between the price levels of two countries]."[1] In its relative version, PPP theory asserts that exchange rate variations should match changes in relative price levels. The empirical implication of the theory is that the real exchange rate series, defined as the ratio between international prices measured in domestic currency and domestic prices, should be stationary.

Although some variant of PPP has been a building block for modeling exchange rates behavior in the long-run, empirical evidence on its validity is, at best, controversial (see Froot and Rogoff, 1995, Rogoff, 1996, Sarno and Taylor, 2002, and Taylor and Taylor, 2004.). PPP does not seem to hold in the short-run at all, which fits assessments by economists that it should not hold continuously. As to the long run, empirical evidence shows very low real exchange rate convergence speed. The literature finds half-lives of three to five year in studies using long time spans (Frankel, 1986 and 1990, Mark, 1995, Lothian and Taylor, 1996) and using panel data (Frankel and Rose, 1996, Oh, 1996, Wu, 1996, Wu and Wu, 2001, and Lothian 1997). More recent studies exploring nonlinearities (Obstfeld and Taylor, 1997, Taylor, Peel and Sarno, 2001, Taylor and Peel, 2000, and Juvenal and Taylor, 2008) and heterogeneity (Crucini and Shintany, 2008, Imbs et al., 2005) were able to uncover higher speeds of exchange rate convergence to PPP. Recent developments on this literature have also explored the impact on real exchange rate dynamics of endogenous tradability (Naknoi, 2008) and dual inflation (Világi, 2007).

Despite the recent controversy regarding the real exchange rate (RER) speed of convergence, there is consensus in the literature that the exchange rate departs from its PPP level for long periods of time. In

[1] See Officer (1976) for a very nice description of the origins of the PPP theory.

this paper we are interested in the behavior of the deviations from PPP themselves. More specifically, we want to investigate whether the RER alternates periods of appreciation with periods of depreciation, as well as establishing the duration of such episodes. Our work builds on Goldfajn and Valdés (1999), who study the pattern of appreciation episodes.

Transportation costs and barriers to trade may prevent a complete international arbitrage of prices and produce RER departures from its PPP level, as recognized early on by Cassel (1922). In the extreme case of nontradable goods, there is no international price arbitrage at all. Price indices used to compute RERs always include some fraction of nontradable goods, so that part of the observed RER changes reflects shifts in relative prices of nontradables. We are interested on the portion of RER variation related to relative prices of tradable goods. To capture it, we estimate RER misalignments, defined as the difference between the observed RER and its estimated equilibrium value. Equilibrium RERs are estimated by cointegrating RER with fundamentals, which are variables that affect the relative prices of trabable and nontrabable goods.[2]

A Markov Switching Model (MSM) is then used to model RER misalignments as a stochastic autoregressive process governed by two states with different means and variances. This econometric characterization estimates the mean and the variance of the misalignment under each regime, as well as the probability of transition between regimes. If a MSM has a better fit on misalignments than an autoregressive model, the straightforward interpretation is that appreciations or depreciations episodes were observed in that country, and, with the estimated transition probabilities, we can infer the probability the economy is in each regime at each point in time.

Goldfajn and Valdés (1999) – GV, hereafter – study appreciation episodes through a statistical procedure. GV assumes that RER reverts to a time-varying long-run equilibrium value and they are especially concerned about how real appreciations revert to the equilibrium level. They estimate a long-run

[2] We are aware that different consumer preferences and production patterns across countries may also prevent the RER from achieving the PPP level, even if prices are perfectly arbitraged by international trade. The RER misalignment we compute do not control for this source of PPP failure though.

relationship among RER and economic fundamentals using cointegration techniques and then construct a overvaluation series, comparing the observed RER and the predicted value obtained from the cointegration relationship. They identify an appreciation episode as a period in which the RER misalignment is above a pre-established level defined as threshold for appreciation episodes (e.g., 15 percent or 25 percent). The appreciation ends when this difference hits a second threshold (5 percent) associated with the existence of no appreciation. The number and dynamics of appreciations are studied for alternative thresholds, using a statistical framework. As expected, the number of appreciations is negatively related to the value of the chosen threshold.

An important disadvantage of that approach is that the threshold used to identify appreciations is arbitrary. Moreover, the threshold used to classify appreciation episodes is the same for all countries, without taking into account the particular behavior of each exchange rate series.

In this paper, we characterize both real appreciation and depreciation episodes using a methodology, the MSM, that do not rely on the researcher's discretion to decide whether a departure from equilibrium RER is large enough to be considered a meaningful economic episode (that is, a real appreciation and depreciation).

There are a few studies that use the MSM to model exchange rate behavior. Engel and Hamilton (1990) develop a regime-switching model to capture the long swings on the dollar nominal exchange rate and show that it has a better predictive performance than a simple random walk model. Kaminsky (1993) models the dollar behavior with a MSM in order to identify the peso-problem. Martinez-Peria (2002), particularly interested on exchange market pressure, models the mechanics of swings from tranquil to speculative attack regimes (and vice-versa). Bonomo and Terra (1999), focusing on the political economy of exchange rate policy in Brazil, use a MSM to identify whether real exchange rate misalignments have different regimes, and investigate the political factors that may influence the shifts from one regime to another.

Our main findings are the following. In the first place, for some countries we find no evidence that RER misalignments follow more than one regime, that is, the exchange rate behavior in those countries present neither appreciation nor depreciation episodes. Second, for some we states that can be understood as appreciation and depreciation states, that can be followed – or not – by sudden reversals.

Third, our results suggest that the use of a unique RER misalignment threshold for all countries to classify appreciation episodes, as done in GV, is not adequate. We find alternative regimes for some of the countries for which GV did not detect any appreciation episode, that is, whose departures from the equilibrium RER are not large enough according to GV's metric. In our methodology, the threshold that determines episodes of appreciation/depreciation is endogenously determined and takes into consideration the series behavior across time.

Finally, evidence of a different RER behavior under different regimes is found. Appreciated regimes are reported as having higher persistence than depreciated ones.

In the MSM model, the current state of the underlying series is unknown and statistical inference about the likelihood of being on a specific state can be made at each point of time. Hence, it is also possible to markedly establish starting and ending points for real appreciation and depreciation episodes. A comparison between both methods, MSM and GV, is made for the whole set of countries and some remarkable differences appear. Both the number and average duration of misalignments episodes are higher than those figures calculated by GV.

This paper is organized as follows. The next section presents the estimation of the RER misalignments. The third section uses the misalignments estimates as inputs to a two-state Markov Switching Model. The final section concludes.

2. Real exchange rate misalignments estimation

We are interested in studying RER departures from PPP level. Ideally, we would like to measure RER through price indices composed exclusively of tradable goods, showing identical goods compositions. In practice, however, this is not possible. On the one hand, the composition of price indices with exclusively tradable goods, such as the export unit value index, differs significantly across countries. On the other hand, price indices that show less marked diversity in goods composition, such as the consumer and the wholesale price indices, contain a fraction of nontradable goods that is not negligible.

Wholesale price indices (WPIs) are a good compromise between these two features: with a smaller share of nontradable goods than consumer price indices, their composition is more homogeneous across countries when compared to export unit values or producer price indices. Indeed, in a study on PPP that compares the performance of different price indices, Terra and Vahia (2008) find that WPI is the index for which PPP evidence is found for a larger number of countries. Terra and Vahia (2008) also employed export unit values, value added deflators, unit labor costs, normalized unit labor costs and the consumer price index.

Hence, we use WPIs to compute effective RERs defined as:

$$(1) \qquad RER_{rt} = \prod_{s=1}^{n} \left(\frac{P_{rt}}{P_{st} E_{srt}} \right)^{\varpi_{rs}},$$

where P_{rt} is the WPI is country *r* period *t*, E_{srt} is the nominal exchange rate between countries *r* and *s*, and ϖ_{rs} is the share of country *s* in country's *r* total trade.

For our set of 85 countries, we use WPIs whenever possible, in terms of availability or reliability, to construct the RER series. Otherwise, they are replaced with CPIs. We obtained average monthly nominal exchange rates and price indices mainly from the IMF's International Financial Statistics (IFS), covering a period ranging from January 1960 through December 1998. All series were graphically examined in order to avoid data glitches. As in GV, we employed interpolation to fill in missing values whenever price indexes exhibited lacking data for short periods of time. To compute effective RER from equation (1), we consider only trade partners with trade shares over than 4%. We calculated effective real exchange rates using constant weights taken from Goldfajn and Valdes (1996).

In order to control for the nontradable portion in the WPI, we estimate equilibrium RERs and compute RER misalignments as the difference between the observed RERs and their estimated equilibrium values. There is an extensive and evolving literature on the estimation of equilibrium exchange rates (EERs), always coming up with creative new acronyms. Among the different empirical approaches, there are CHEERs (capital enhanced EERs), ITMEERs (intermediate term model based EERs), BEERs (behavioral EERs), FEERS (fundamental EERs), DEERs (desired EERs), APEERs (atheoretical permanent EERs) and PEERs (permanent EERs), whose description can be found in MacDonald (2000) and Driver and Westaway (2005). The models differ basically on the exchange rate definition they use, the time frame they envisage, and the way they model the dynamics.

We are interested in RER changes, which rules out CHEERs and ITMEERs since they focus on nominal exchange rates estimations. Nor are FEERs and DEERs adequate for our case since they do not estimate equilibrium RER directly. They concentrate on estimating either complete macroeconomic models or simply current accounts, resulting in RER consistent with medium term equilibria. APEERs and PEERs do focus on RER, but they are concerned with medium to long run equilibrium values. We would like to control for RER variations caused by actual changes in relative prices of nontradables, hence we are not interested on their long run equilibrium values.

The equilibrium RER estimate adopted in Goldfajn and Valdés (1999) is in the spirit of BEERs, and we will adopt the same approach in this paper. BEERs estimations focus on effective real exchange rates, using interest rate differentials and economic fundamentals as explanatory variables. Theoretically, this is based on the uncovered interest parity condition, where economic fundamentals are used to control for expectations of RER changes.

The method used by Goldfajn and Valdés (1999) consists of estimating a cointegrating relation between observed RER and a chosen set of economic fundamentals, including international interest rates, for each country separately. Its theoretical underpinning, however, differs from that of BEERs. The choice of fundamentals in GV is based on electing the variables that various models had identified as relevant to determine the relative price of nontradables and whose data is readily available for a large set of countries and long period of time. The variables are: terms of trade; openness; government spending; and the international interest rate, whose impact on the equilibrium RER is discussed below. Note that this set of variables does not include all the variables that the literature highlights as important in RER determination. In particular, it does not include productivity differentials to capture the classical Balassa-Samuelson effect.

We choose to follow exactly the procedure used in GV to estimate the equilibrium RERs, in order to be able to compare the Markov Switching methodology we apply in this paper to the statistical method proposed by GV to investigate RER misalignments dynamics. If we chose to estimate equilibrium RERs through a different approach, we would not be able to disentangle potential differences in the identification of RER appreciation events between the use of a different misalignment estimation procedure and the method for identifying the events.

Edwards (1989) presents an RER determination model that can provide a theoretical background to the variables used here. He assumes three types of goods: exportable, importable and nontradable goods, and the RER is defined as the relative price of tradables and nontradables.[3] In a two period framework, under price flexibility and full employment, the model derives the impact of several exogenous variables on the equilibrium RER. See below a short discussion of the impact of these fundamentals on RERs, according

[3] It is important to emphasize once more that here we are not focusing on the relative price of tradables and nontradables. We are concerned with relative price levels across countries, ideally comprised of tradable goods only. However, results from empirical literature, as already discussed above, show that there are no price indices perfectly arbitraged across countries. For that reason, we seek economic variables to control for their nontradable component.

to the framework in Edwards (1989), as well the characteristics of the data used as proxies to these economic factors.

Terms of Trade (TOT): The usual simplification that all countries produce the same varieties of tradable goods is not reasonable in practice. In fact, the goods composition of a country's exports usually differs from the composition of its imports. Obstfeld and Rogoff (1996) point out that the terms of trade, i.e., the relative price of exports to imports, is one of the main channels for the global transmission of macroeconomic shocks. The impact of TOT changes over RER is associated to adjustments on nontradables prices due to demand shifts. Following Diaz-Alejandro's (1982) long-established approach, a (permanent) negative TOT shock causes a drop in real income which, in turn, lowers nontradables prices, resulting in RER depreciation.[4]

Our main source for TOT data is the World Bank's World Development Report, completed with IFS exports and imports prices when necessary. Since the data is available in an annual basis, we follow GV and convert it to monthly data, that is, the yearly data was linearly interpolated using June as the basis month.

Openness (OPEN): This variable is, to some extent, a measure that indicates the degree to which the country is affected by the international environment, since it stands for how closely it is connected to the rest of the world. Following GV, openness is proxied by the sum of exports and imports over GDP. We are aware that openness thus measured is not a good proxy for trade liberalization in a cross country comparison. Other domestic variables unrelated to trade liberalization, such as size and geography, may have a large influence in the differences in openness across countries. However, since such variables do not change significantly over time, it is a reasonable proxy for the case of a single country on the time series dimension. Changes in the GDP ratio of the sum of imports and exports over time in a country should be indeed related to variations in exposure to the international goods markets. As the cointegration

[4] We assume this line of reasoning in the subsequent analyses, even though an opposite result can be reached, depending on whether income or substitution effects prevail (for details, see Edwards, 1989, pages 38 and 39).

with the fundamentals is computed for each country separately, it only captures the time series dimension within each country.

An increase in openness should cause RER depreciation. Trade liberalization reduces the domestic prices of tradables causing a demand shift away from nontraded goods. Under some fairly reasonable cross price elasticities assumptions, nontradables prices should fall, producing a real depreciation.

Size of Government (GOV): A permanent change in the size of government affects RER whenever it triggers demand swings from tradables to nontradables. Countries where the share of government spending on nontradable goods is relative higher than that of private spending should experience equilibrium RER appreciations to follow an increase in the size of government. If government spending lies more heavily on tradable goods, as for instance, in the case of military expenses, then the opposite is true: more government spending would produce RER depreciations.

We use Openness and Real Government share of GDP from the Penn World Tables (PWT 5.0 and 6.0). GV had to combine PWT and World Bank data for those variables, as PWT 6.0 was not available at the time.

Note that we also obtained monthly terms of trade, government consumption and the degree of openness through linear interpolation of yearly data. We are aware that these three variables do not necessarily follow steady monthly growth rates; nevertheless we believe that this should not impair our empirical analysis. Firstly, if the within year swings for these fundamentals were perfectly symmetric, they would have no impact on the estimated coefficients, nor on the misalignment measures. Hence, if the variables' growth rate within a year is not too asymmetric, errors in misalignment estimation should not be large. Secondly, even if some countries undergo larger shocks for short periods, of say, a couple of years, estimated coefficients should not be much affected since we are covering a period of 38 years. Finally, the different regimes captured by the MSM do not present within year cycles. Therefore, possible errors from the linear interpolation do not seem to affect the identification of RER regimes, which is the ultimate goal of this study.

International Interest Rate (TBAA3M): Lower international interest rates strengthen capital flows and thus generate RER appreciation in small open economies. One should note that capital flows respond to the differentials between international and domestic interest rates. To use the international rate only is not the most appropriate choice, since domestic rates may change over time. Nevertheless, we chose to follow GV, and we use simply the US 3-Month Treasury Bill as international interest rate.

GV's method relies on the implicit assumption that RER can be decomposed into a permanent component, that is, a nonstationary I(1) series, and a second element that has stationary behavior. The integrated component represents those changes in RER that do not vanish over time, namely, changes in RER equilibrium, which is explained by the fundamentals. The I(0) elements are the short-run misalignments that disappear over time.

Following GV, we also applied the two-step cointegrating relationship estimation procedures proposed by Hargreaves (1994). The first step consists in testing for the existence of cointegration among the effective RER and the fundamentals series for each country separately. Firstly, all series (RER and fundamentals) were tested for the presence of unit roots using Augmented Dickey-Fuller techniques. We subsequently apply the Johansen (1988) test to look for cointegration among RER and fundamentals. If results establish the existence of at least one cointegrating relationship, we perform an univariate estimation method to estimate the cointegrating relationship.

The Hargreaves (1994) procedure has two main advantages. Firstly, it allows us to test, through the Johansen framework, which variables should be considered in the cointegrating vectors. Moreover, the estimation of a single cointegration relationship prevents a common problem that arises when dealing with multivariate estimation. It is often the case that, when more than one cointegration relationship is identified, the signs of the elements of the alternative cointegration vectors are opposite, meaning that those variables may have distinct long-run relationships. This question is bypassed using a single-equation methodology to estimate the cointegration relationship, once cointegration has been determined using Johansen framework.

There are a number of different estimation techniques available to estimate cointegration vectors using univariate methods: OLS, Dynamic OLS, Fully Modified OLS or ADL methods. GV use a dynamic OLS, considering that "Stock-Watson approach is preferable to simple OLS estimation because it allows for possibly endogenous fundamentals and corrects for serial correlation of the residuals" (GV, p. 234). We choose OLS estimation that yields a superconsistent estimator under the null hypothesis of cointegration (Hamilton, 1994, p. 587).[5]

In sum, to compute the equilibrium RER we estimate the following equation:

(2) $$RER_{rt} = \alpha_0 + \alpha_1 TOT_{rt} + \alpha_2 OPEN_{rt} + \alpha_3 GOV_{rt} + \alpha_4 TBAA3M_{rt} + \varepsilon_{rt},$$

for each country r separately. The estimated coefficients for the fundamentals are presented in Table 1. They show that more appreciated exchange rates are associated with lower international interest rates for 82% of the countries, higher government spending for 81%, lower openness for 58%, and positive terms of trade shock for 60% of them.

Once a cointegrating vector has been found, an equilibrium RER series is constructed by applying the cointegrating vector to the fundamentals series. At each point in time, the RER misalignment is calculated as the difference between the observed RER and its predicted equilibrium value, that is, we compute:

(3) $$m_t = \widehat{RER}_t - RER_t,$$

[5] The use of alternative estimation techniques yields estimation uncertainties, which is one of the uncertainties currently acknowledged in estimating real equilibrium exchange rates. Other uncertainties are related to model uncertainty, that is, to the set of fundamentals employed to derive the equilibrium exchange rate; and uncertainty related to the use of time series vs. panels of different sizes. We thank an anonymous referee for this point.

where $\widehat{RER}_t$ is the predicted RER value from equation (2). We then use MSM to study the dynamics of the RER misalignment m_t.

3. Misalignments and MSM

A preliminary assessment of misalignment dynamics indicates that it can be characterized as a stochastic process with substantial degree of persistence. In fact, for many countries studied, misalignments seem to be up for long swings, that is, to move in one direction for long periods of time. Additionally, these movements are frequently succeeded by sudden shifts in values in the opposite direction. This stylized fact is in harmony with GV's observed RER inertia when outside its equilibrium path. Besides, it seems to be coherent with the low probability of smooth returns of appreciation episodes.

The long swings followed by sudden reversals suggest the Markov Switching Model as a suitable description for the RER misalignment path. The MSM deals with settings in which discrete shifts in regime are possible, that is, the existence of "episodes across which the dynamic behavior of the series is markedly different." (Hamilton, 1989, p.358). Additionally, we do not need to have any previous knowledge of which regime is governing the stochastic process at each point in time. In fact, this becomes a probabilistic inference problem in which every observation is assigned a probability of being originated from a specific regime.

We want to identify whether distinct regimes for RER misalignments exist. At first, we presumed that overvalued and undervalued states will arise. The estimation may either confirm the existence of two misalignment states, or it may show that only one regime is the best description for the misalignment, that is, that an autoregressive process fits the available data better.

As previously mentioned, a straightforward advantage of this model is that it endogenously determines the existence of alternative regimes. This is particularly relevant if we take into consideration that the level of misalignment that may exert an effect on economic outcomes may be quite different on a country by country basis. Depending on alternative social and economic structures – such as institutions or exchange rate arrangements, for example – the same level of departure from the equilibrium RER may or may not be considered a relevant economic episode (a real appreciation or depreciation). Indeed, it is reasonable to suspect that appreciations and depreciations may be characterized by distinct distances from the equilibrium RER. These questions are examined here.

The MSM model and its empirical implementation to RER misalignments are presented in the next subsection. This is followed the presentation of the results, with comparisons with those from GV.

3.1 Markov Switching Model implementation

The RER misalignment is modeled as following an auto-regressive stochastic process ruled by alternative states which have different means and variances. We employed a Markov Switching Model to characterize the process, and it may be described as follows:

(4) $$m_t - \mu(s_t) = \emptyset\left(m_{t-1} - \mu(s_{t-1})\right) + \sigma(s_t)\varepsilon_t$$

where m_t is the RER misalignment, $\{\varepsilon_t\}$ is a sequence of i.i.d. N(0,1) random shocks, and s_t is an unobserved variable governing both the mean term μ and the variance σ. The variable s_t is usually referred to as a state variable because it defines the regime of the stochastic variable at time *t*. Basically, the stochastic process is an autoregressive process that fluctuates around two different means, with two different variances. Hence, the dynamics of the stochastic process is defined by the interaction of the autoregressive coefficient $\emptyset$, the Gaussian innovations $\varepsilon_{t,}$ and the states s_t.

The variable s_t is modeled as a discrete-value stochastic process that can assume distinct values and we admit only two possible states, henceforth labeled states one (depreciated) and two (appreciated). Consequently, the actual misalignment series may have observations that can come from alternative stochastic processes with two different means and possibly also different variances. As usual, s_t is modeled as a first-order Markov process in which the probability distribution of the current state depends only on the state of the stochastic variable in the immediately preceding period.

Let $\{s_t\}_{t=1}^{T}$ be the sample path of the Markov process described above. A transition probability matrix can be defined by:

$$(5) \qquad P = \begin{bmatrix} p_{11} & 1 - p_{22} \\ 1 - p_{11} & p_{22} \end{bmatrix}$$

where p_{ii} is the probability that the economy will remain in state *i* next period, defined as $p_{ii} = \frac{exp(\beta_i)}{1+exp(\beta_i)}$. The transition probabilities, written as logistic functions from parameters β_i, are time invariant. Our main focus in this paper is on the probability of being, in a given point of time, in a specific regime (with a higher or lower mean).

The model is estimated using maximum likelihood. Sample misalignments $\{m_t\}_{t=1}^{T}$ are assumed to follow a stochastic process characterized as a Gaussian i.i.d. mixture that depends on the unobserved sample path state variable. Therefore, m_t density, conditional on s_t has a normal distribution:

$$(6) \qquad f(m_t|s_t = i; \alpha_i) = \frac{1}{\sqrt{2\pi\sigma_i}} exp\left\{\frac{[(m_t-\mu_i)-\emptyset(m_{t-1}-\mu_i)]^2}{2\sigma_i^2}\right\}$$

for $\alpha_i = (\mu_i, \sigma_i, \emptyset)$ a vector of population parameters and *i* = 1,2. It is important to remember that the normality assumption regards the conditional rather the unconditional distribution of misalignments. The actual misalignment series are supposed gaussian mixtures and may have completely different theoretical/empirical distributions. In fact, Jarque-Bera tests were applied for each sequence and the null hypothesis was not rejected for only 9 of the 85 countries sampled.

The estimation problem reduces to finding a set of parameters that maximizes the log likelihood function subject to the usual constraints on transition probabilities. Once a set of parameter estimates has been found, a sequence of estimates for the (constant) transition probabilities is also available. Such estimates can be used to form filtered probabilities which assess the likelihood of the states at each point in time.[6]

3.2 Results

MSM estimation relies basically on an EM algorithm developed in Hamilton (1989) to maximize the log likelihood in order to avoid the computational intractability issue. Although this algorithm is considered a well-established, robust and stable procedure, there are a few details to be considered on its implementation.[7]

Diebold, Lee and Weinbach (1994) recall that, as usually noted in the literature, "EM algorithm gets close to the likelihood maximum very quickly, but then takes more iterations to reach convergence" (p. 296). The number of iterations might be closely associated with the shape of the maximum likelihood function. We found a flat region neighboring the estimated maximum for several of the series under investigation. Also, whenever convergence is achieved, since we obtain the solution numerically rather than analytically, the resulting maximum likelihood parameter estimates have to be considered, in principle, a local maximum. Alternative start up parameters were tested to check whether those estimates can be considered a global maximum.

After the MSM has been properly estimated, it is necessary to test if misalignments are more likely to have been originated from a random mixture distribution (that is, two regimes) rather than from a standard AR(1) stochastic processes. Hamilton (1994) warns that usual LR tests used to verify misspecification are not appropriate in this context because LR tests regularity conditions may not be attained. The null hypothesis that describes the N_{th} state is not identified when the researcher tries to fit a N-state model when the data generating process has $N-1$ states (in our case, a plain AR(1) model).

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[6] Alternatively, smoothed probabilities which also take into consideration the information available in the succeding periods (t, t+1, t+2,..., T) can be calculated. Since they use the whole set of data available for each country, they are expected to be more accurate and hence provide better inferences on the state realized at each point of time.

[7] We thank René Garcia for providing a Fortran program used for estimating the Markov Switching Model.

Garcia (1998) derives asymptotic statistics of the LR tests for a variety of Markov switching models using the asymptotic distribution theory employed when a nuisance parameter is not identified under the null hypothesis.

An alternative hypothesis of two regimes was tested against the AR(1) null. The likelihood ratio statistics for each country is reported in Table 2 and the critical values vary with the auto-regressive factor. The null hypothesis of an AR(1), at a 5% confidence level, could not be rejected for 11 of the 85 total sampled countries. They are Bahrain, Bangladesh, Canada, Hong Kong, Liberia, Nepal, Pakistan, Saudi Arabia, Sierra Leone, Singapore and Tunisia. These countries are better characterized by a model AR(1) in which misalignments fluctuate around a constant mean with a specific (perhaps outsize) variance, in opposition to a stochastic process that is the combination of other two processes with different means and possibly different variances. Pakistan misalignments, for example, are usually not very large and are subject to a somewhat high degree of volatility, particularly from 1985 onwards. Although cross-section comparisons are not made here, loosely speaking, these countries seem to share a common characteristic: the departures from RER are usually smaller when compared to the whole set.

For the remaining 74 countries, 10 were best described by regimes that had not only different means but also dissimilar variances, as shown in Table 2. The relatively small sample is not enough to authorize inferences on whether there is a relation between the second moment of the stochastic process with the first moment of the regimes (i.e., if appreciations are less or more volatile than depreciations). For four countries – Burundi, Central Africa, Denmark and Kuwait – the lower mean regime is also associated with lower volatility. Zaire, Jamaica, Liberia, Mexico and Paraguay illustrates the opposite: lower means are associated with higher volatility when compared to those linked to the higher mean regimes. For El Salvador, however, although likelihood increases when a two-variance model is considered, the difference of the variances is not statistically significant.

As previously mentioned, we are concerned with the plausibility of two means. The two states are expected to take account of RER appreciations vis-à-vis RER depreciations. However, although for many countries this result seems to hold, another outcome is also present: the model identifies a regime with a mean quite close to zero and another in which it is very far from zero. Cameroon, Peru and Rwanda are examples of this pattern.[8]

An important task is to identify the state in which the economy is at each point in time, more specifically, to identify overvaluation and undervaluation episodes. GV distinguish overvaluation episodes by exogenously setting a threshold for the misalignment, and whenever the misalignment surpasses this threshold (for instance 15%) for two consecutive months, an overvaluation episode is said to start. The end of an episode is established for the first time when the overvaluation measure returns to a level under or equal to the 5% distance from the equilibrium RER.

In the MSM framework, this task can be accomplished by using the estimated transition probabilities to calculate the probability the economy is in each of the states, which are denoted filtered probabilities. When the filtered probability of depreciated states, given the available data, is close to 1, there is strong evidence that the misalignment is in a depreciated regime. Conversely, when it is close to 0, there is support for the hypothesis that the observed misalignment comes from a lower mean regime. The inference about whether a misalignment may have been originated from one regime or another can therefore be performed based on these filtered probabilities.

However, a certain degree of arbitrariness is involved here: we must adopt filtered probabilities thresholds. Most empirical applications available in the literature use a 0.50 threshold. When the calculated filtered probability is above this maximum value, the observation is considered to belong from the specific regime.

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8 The latter, for instance, has a mean close to zero (μ_2=-1.52) and another considerably higher (μ_1=149.54). Apparently, it is a sign of a particular deviation incident occurred in 1994. For this reason, substantial asymmetries on the mean parameter for the alternative regimes can be verified.

A different approach is adopted here. A higher cutting edge is defined so that the observation is considered a relevant episode. Figure 1 displays a histogram of the depreciated state filtered probabilities encompassing the 85 countries analyzed. It is clear that most of the estimated probabilities are either close to zero or one, and also that movements between the two extremes are fast.

Since 89.6% of the 32,343 filtered probabilities calculated are located within a 0.30 distance from the extremes, this border line was adopted. As a consequence, RER appreciation episodes are defined as those observations with associated appreciation filtered probability higher than 0.70. The same is true for RER depreciations: the limit for filtered probabilities to identify depreciation episodes is also set at 0.70. Note that a filtered probability in a two-state model is the complement of the corresponding alternative filtered probability. For instance, a 0.85 appreciation filtered probability is equivalent to a 15% chance that this particular observation has been originated from the depreciated state.

Depreciated State Probability Histogram

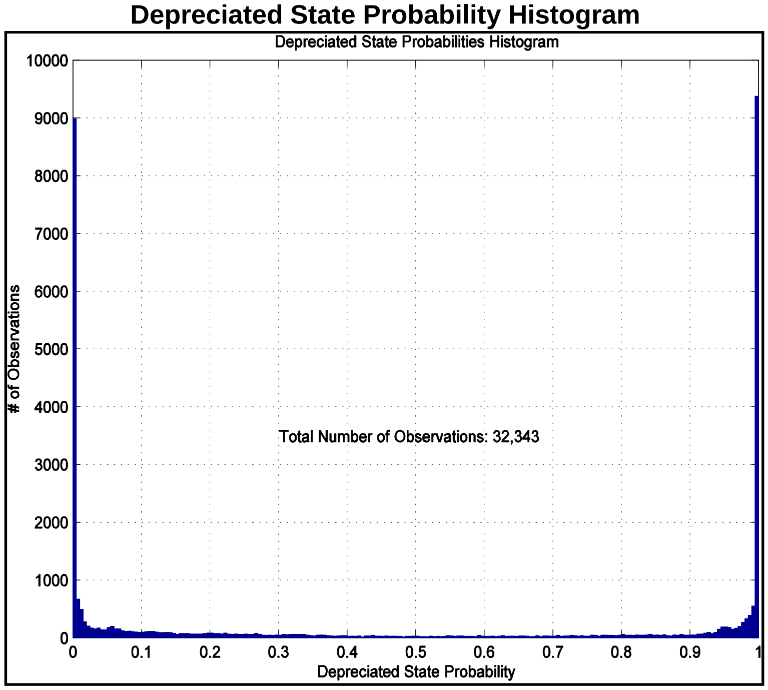

Figure 1

The resulting episodes were compared with those observed when GV methodology is applied. Table 3 tabulates, for each country, the number of episodes and average durations. For comparison, the table also presents GV figures. For most of the countries, these indicators are higher than those calculated using GV methodology. In general, appreciated RERs are expected to hold for longer periods, and end with large devaluations.

Figures 2 and 3 provide a visual comparison between the MSM and GV for Belgium and Brazil, respectively. The first two graphs in each figure included display the RER misalignment series and the filtered probability for the depreciated regime. The next two graphs show the appreciation and depreciation episodes using GV methodology. Finally, the last two graphs depict the appreciation and depreciation episodes derived from MSM.

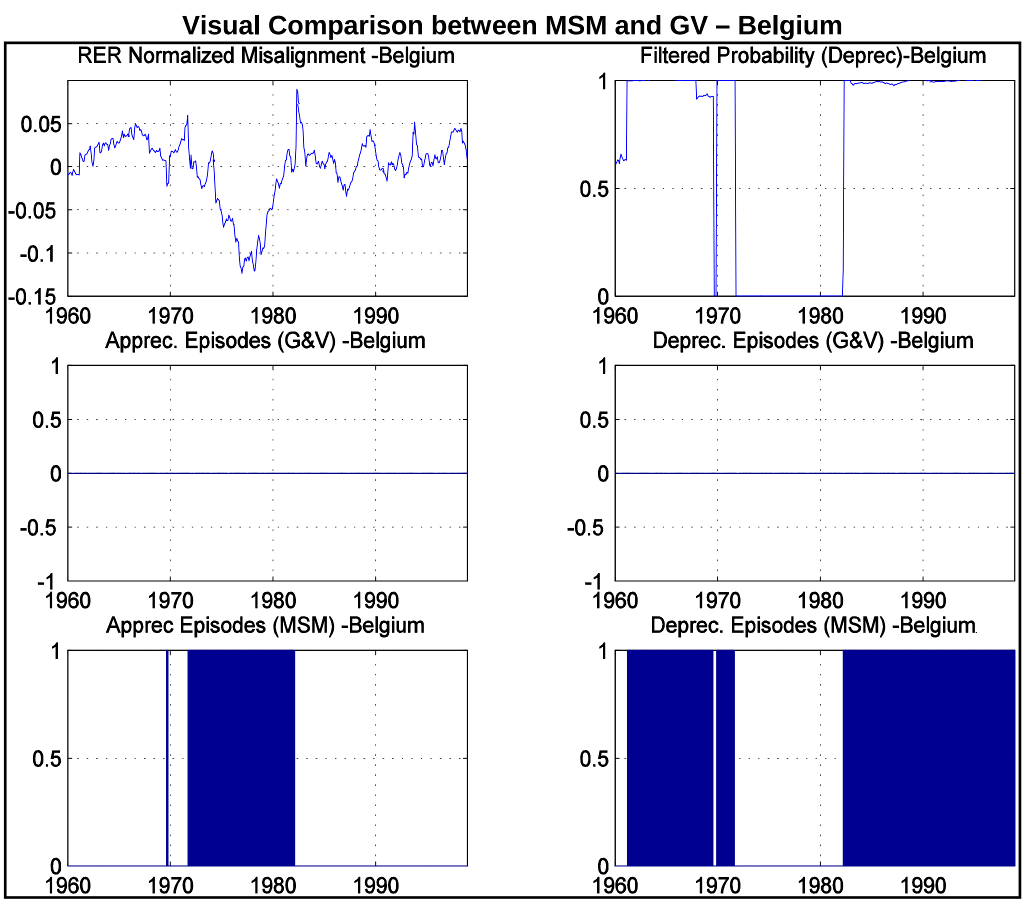

Figure 2

For the case of Belgium, in Figure 2, the GV does not identify any episodes, while the MSM does identify both appreciation and depreciation episodes. As for Brazil, in Figure 3, the two methods agree in the identification of some of the episodes, but MSM identify episodes that are not recognized by GV. Differences in the identification of appreciations and depreciations in the first half of the 1960's are noteworthy. This period was characterized by an intense RER volatility due to the increasing inflation and nominal exchange rate devaluations. MSM shows an appreciation episode in the late 1970's not captured by GV framework. Both methodologies agree in the identification of the appreciation episodes in the end of the 1980's, when Brazil was on the verge of hyperinflation, and after 1994, when a stabilization program reduced inflation and a nominal exchange appreciation ocurred.

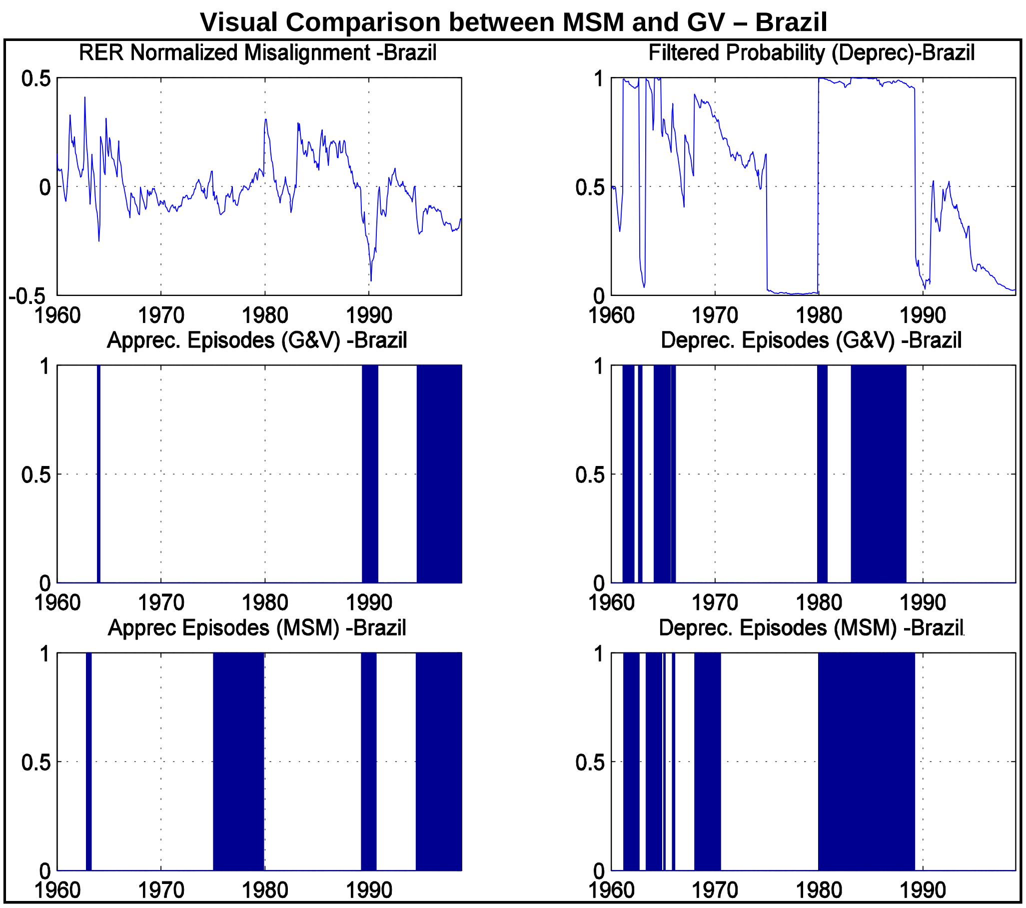

Figure 3

For the other countries, the same patterns described above can be observed. We have included an Appendix presenting figures for selected countries, with some interesting results. Canada is a case similar to Belgium: according to GV there are no episodes and MSM identifies several appreciation and depreciation episodes. For Greece, GV method does not identify any depreciation episodes, while for the MSM the RER is depreciated in most periods. For Turkey, the GV identifies more appreciation episodes than MSM, while the converse is true for depreciation episodes. In the cases of Argentina and New Zealand, GV identifies more episodes than MSM, both appreciated and depreciated. Colombia and Hong Kong are two cases in which there is a disagreement between the two methods. The years around 1980 for Colombia and in the late 1990's for Hong Kong are identified as appreciated periods according to GV, and as depreciation episodes using MSM. GV method identifies many more appreciation episodes than MSM for the United States and for South Africa, and more depreciation episodes for Korea. GV and MSM identify basically the same appreciation episodes for Ethiopia, but the two methods disagree in the identification of RER depreciations. Finally, the identified episodes for Uruguay and for Zaire are very similar using the two methodologies.

It is worth mentioning, however, a negative aspect of using estimated filtered probabilities in order to characterize appreciation and depreciation episodes. We can observe a degree of inertia on filtered probabilities and there are episodes when it is not possible to establish a direct relationship between changes in misalignment and the assigned filtered probabilities.

Nevertheless, we find positive evidence that MSM is an appropriate framework. For some of the countries whose RER misalignments are small using GV metric, the null hypothesis that the series follow an AR(1) cannot be rejected, that is, there is no evidence of either appreciated or depreciated episodes. However, in many cases the MSM suggests the existence of two regimes with means significantly different. This is precisely the case of Austria, Belgium and Denmark, among others. That is, for many countries that GV methodology did not indicate the occurrence of appreciation or depreciation incidents, the MSM appointed episodes. This again supports the idea that a common threshold for all countries should be avoided.

4. Conclusions

This paper investigates whether RER misalignments – defined as deviations from its equilibrium value – may be characterized by a switching regime model in which the RER misalignments fluctuates around two different means, with possibly also different variances. Using a Markov Switching Model governed by two states we are able infer the probability the RER misalignment is in each state at each point in time. Goldfajn and Valdés (1999) have also studied misalignment patterns to investigate RER appreciation episodes. Their methodology relies on a pre-established threshold to identify appreciation episodes, which is common to all countries. That is, appreciation episodes are defined when the misalignment exceeds an ad hoc limit. Nonetheless, it is far from certain whether this common threshold is consistent with different economic structures observed among countries. As a consequence, an endogenously determined limit seems to be more adequate. Additionally, behavioral asymmetries on RER misalignments between regimes may exist since the alternative regimes may present diverse patterns of persistence and volatility.

The most common switching regime model implemented in the empirical literature – two-state MSM – was implemented on RER misalignments for 85 countries. RER misalignments are defined as departures of the RER from its equilibrium value, obtained through estimating a cointegrating relationship between actual RER and a set of economic variables.

The MSM estimation for each country provided both similar and different outcomes when compared to the results available in GV. Firstly, the AR(1) null hypothesis cannot be rejected for some countries in which GV would not signal the existence of either appreciation or depreciation. Conversely, for other countries in the same situation, the null hypothesis is rejected. This result can be understood as evidence that countries do not share the same thresholds from which RER misalignments should be considered relevant economic episodes.

Additionally, for some countries, the model apparently identifies a state in which the RER fluctuates around its equilibrium value for a long interval and another where significant misalignments can be observed. This can be a result of the particular probabilistic structure assumed and suggests the investigation of whether a three-state switching model is a better fit to the available data. Consequently, it is doubtful whether filtered probabilities provide an accurate classification of appreciations/depreciations for those countries.

It is worth mentioning that our findings lend support to the presence of distinct regimes also for the variance for countries with RER misalignments governed by two states. Nevertheless, we are not able to identify a relation between RER volatility and its mean, that is, if depreciated regimes have higher or lower variance than appreciated ones.

In general, as shown by the state transition probabilities, appreciation (lower mean) episodes have higher persistence and thus last longer than depreciations (higher mean). This finding may be consistent with a line of reasoning adopted by GV, when they find that undervaluations are usually less prone to move back to equilibrium by means of smooth returns. A downward rigidity of prices, together with different degrees of tolerance with booms and recessions on the part of policymakers, may cause this asymmetry.

As suggested in GV, it would be interesting to investigate whether the reversion of appreciated and depreciated episodes are led by nominal exchange rate movements or by cumulative differential inflation. This may shed some light over the mechanism that leads to a higher persistence of appreciation episodes.

Moreover, there are alternative assumptions that may be tested. For example, that the actual real exchange rate fluctuates around the equilibrium value and that there are other states of misalignment, that is, the real exchange rate of a country may fluctuate around its equilibrium value for longer periods and, occasionally, may deviate and remain stable in a misaligned state for a while. The number of such occurrences and whether these states are similar or different is a matter for future empirical estimation.

These questions may be addressed in the future estimating three-state MSM or a Hamilton's model extensions in which time-varying transition probabilities are explained by economic variables. Sarno and Taylor (2002) show that relative PPP holds once a three-regime model is applied to the real exchange rate. A better model fit may enhance the characterization of RER appreciation and depreciation episodes. Another alternative may be the estimation of non-linear patterns of adjustments, which presumes that the degree of adjustment depends on the distance from equilibrium.

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Appendix: Tables and Figures

Table 1: Cointegration Vectors

	Terms of Trade	Government	Openess	Interest Rate	Trend	Constant
Austria	(0,256)	(0,089)	(1,527)	(0,631)		162,179
	0,105	0,078	0,313	0,058		20,825
Belgium	(0,866)	0,394	(0,902)	(1,388)	(0,100)	189,043
	0,099	0,042	0,151	0,105	0,006	11,968
Denmark	(0,038)	(0,060)	(1,557)	0,206		147,000
	0,120	0,105	0,165	0,127		20,607
Finland	(1,109)	0,570	(4,337)	(3,517)	0,068	277,086
	0,124	0,072	0,438	0,170	0,008	17,608
France	(0,287)	0,611			(0,089)	131,655
	0,068	0,130			0,005	10,606
Germany	(0,373)		0,395	(1,299)		144,219
	0,064		0,583	0,159		11,856
Greece	(0,018)	0,667	(1,084)	(1,009)	0,001	89,059
	0,059	0,109	0,329	0,083	0,006	8,151
Ireland	0,139		(1,670)	(0,027)		119,323
	0,031		0,115	0,107		3,221
Italy	0,210	0,896	5,430	0,074		(29,618)
	0,047	0,073	0,503	0,124		13,818
Netherlands	0,526	0,551	2,636	(0,201)		(43,658)
	0,082	0,028	0,123	0,057		11,317
Norway	0,280	(1,901)	(3,093)	0,387		270,035
	0,021	0,102	0,234	0,129		6,810
Portugal	(0,062)	0,756	4,980	0,196	(0,324)	46,595
	0,053	0,052	0,347	0,128	0,012	8,376
Spain	(0,030)	0,750	(0,249)	(1,201)		92,722
	0,029	0,054	0,179	0,121		3,160
Sweden	0,110	(0,053)		(0,062)		101,974
	0,143	0,098		0,241		20,981
Switzerland	(0,077)	0,129	(3,598)	(0,904)	(0,033)	147,521
	0,160	0,126	1,158	0,168	0,014	16,636
United Kingdon	(1,335)	0,967	2,512	(0,894)	0,022	125,227
	0,092	0,096	0,238	0,096	0,005	14,208
Argentina	(0,378)		(0,911)	(1,428)		121,991
	0,042		0,265	0,252		5,852
Bolivia	0,171	2,006	(7,855)	2,230		121,894
	0,087	0,378	0,625	0,644		24,604
Brazil	0,318	3,890	2,614	3,164		(54,253)
	0,030	0,469	0,307	0,393		16,635
Canada	(0,192)	0,341	(0,478)	0,754		108,774
	0,044	0,028	0,245	0,087		5,230
Chile	0,228	0,924	(0,869)		(0,031)	43,498
	0,017	0,091	0,114		0,009	5,553
Colombia		2,688	0,417	(0,966)		(2,943)

	Terms of Trade	Government	Openess	Interest Rate	Trend	Constant
		0,143	0,212	0,143		3,264
Costa Rica		0,441	(2,026)	0,166		104,405
		0,031	0,360	0,216		8,013
Ecuador	(0,707)	0,473		2,782		120,952
	0,031	0,143		0,306		10,225
El Salvador	(0,379)	0,318		(3,964)		148,699
	0,063	0,109		0,315		4,937
Guatemala	(0,199)	0,588	1,591	(1,133)		59,713
	0,047	0,067	0,522	0,232		12,320
Haiti	0,066		(0,596)	(0,235)	(0,151)	167,642
	0,059		0,327	0,275	0,005	7,329
Honduras	(0,453)	1,177	(2,668)	(1,549)		160,407
	0,104	0,068	0,537	0,392		16,763
Jamaica	(0,643)	0,850	0,178	(2,768)		70,379
	0,082	0,034	0,134	0,302		4,858
Mexico		(0,228)	2,747			62,977
		0,053	0,344			3,896
Paraguay		0,259	1,438	(1,107)	(0,084)	56,533
		0,055	0,260	0,287	0,011	5,284
Peru	2,260	8,450	38,385	(0,000)		(794,825)
	0,193	0,548	1,815	1,057		29,783
Trinidad Tobago	(0,211)	0,433		2,455		88,267
	0,021	0,040		0,356		4,912
United States		4,443	3,354			(43,647)
		0,337	0,616			16,583
Uruguay	0,399	(0,756)	5,037	(0,078)		(31,912)
	0,084	0,264	0,596	0,414		18,223
Venezuela	0,116	1,202	6,241	(2,328)		(82,124)
	0,031	0,089	0,559	0,227		8,426
Australia	(0,667)	1,474	(3,351)	(0,794)		180,013
	0,044	0,139	0,479	0,118		9,969
Indonesia	0,330	0,647	(1,407)	(4,669)		74,141
	0,058	0,209	0,520	0,459		10,733
New Zealand	(1,110)	(0,149)	(8,539)			371,321
	0,070	0,113	0,873			16,521
Papua New Guinea	0,214	0,011			0,086	45,844
	0,023	0,055	0,007			5,708
Bahrain		0,124		0,436		77,306
		0,025		0,172		4,500
Bangladesh	(0,459)	0,553			0,124	87,115
	0,094	0,200			0,016	5,683
Hong Kong	(1,981)	(0,149)	(3,580)		0,074	324,296
	0,408	0,033	2,132		0,016	43,950
India	0,503	6,339	(1,824)	(2,580)		(0,046)
	0,132	0,342	0,344	0,293		24,681
Israel	0,645	0,467	(0,101)			2,511
	0,122	0,040	0,074			13,533

	Terms of Trade	Government	Openess	Interest Rate	Trend	Constant
Japan	(0,415)		(5,383)	(1,017)	(0,246)	277,845
	0,045		0,526	0,248	0,010	12,523
Jordan		0,581	0,242	(1,875)		15,470
		0,017	0,139	0,090		6,716
Korea	(0,118)	0,421	(1,594)	(3,105)		131,034
	0,127	0,079	0,273	0,245		17,961
Kuwait		(0,055)	(0,010)	(0,076)	(0,065)	127,356
		0,049	0,048	0,162	0,007	5,232
Malaysia	(0,203)	0,326	0,692	(0,101)		52,255
	0,028	0,006	0,165	0,107		4,590
Nepal			(2,928)	(1,474)	0,244	88,067
			0,213	0,132	0,004	4,046
Pakistan	0,000	1,827	1,706	(1,698)		(5,293)
	0,029	0,130	0,125	0,127		6,895
Philiphines	0,196	(0,030)	3,603	(0,260)		26,951
	0,050	0,030	0,495	0,237		9,599
Saudi Arabia		(0,813)	(0,595)	(2,328)		191,720
		0,081	0,118	0,306		7,025
Singapore	(5,534)	0,042	(0,536)	(0,491)		624,551
	0,409	0,016	0,709	0,120		50,067
Sri Lanka	0,217	(0,107)	(10,215)	(1,085)		273,111
	0,087	0,086	0,446	0,453		15,968
Thailand	(0,076)	0,434	1,520	(1,927)		61,707
	0,041	0,048	0,348	0,179		11,761
Turkey	(0,353)	0,484	1,216	(1,055)		104,267
	0,048	0,108	1,142	0,343		23,275
Algeria		0,994	8,937	(0,695)		(122,775)
		0,059	0,197	0,333		6,792
Burkina Faso	0,055	0,880	(2,782)	(2,388)	0,247	66,318
	0,089	0,290	0,405	0,367	0,019	10,076
Burundi	(0,096)	1,406	2,708	(2,786)	0,137	(42,223)
	0,017	0,148	0,213	0,302	0,015	12,202
Cameroon	0,484		(2,422)	(0,660)		99,845
	0,074		0,874	0,374		13,897
Central Africa	0,111	0,690	(1,813)	(1,572)		143,328
	0,024	0,098	0,140	0,243		3,894
Zaire	0,332	0,662	(1,438)	(4,906)		80,923
	0,068	0,118	0,198	0,442		10,105
Congo	(0,060)	0,489	(0,018)	(1,083)		69,277
	0,008	0,026	0,109	0,163		5,158
Egypt	0,119	2,262	(12,751)			174,381
	0,046	0,094	0,710			8,093
Ethiopia	(0,125)	3,875	(4,384)		0,084	109,363
	0,060	0,184	0,214		0,012	9,140
Gabon	(0,035)	0,288		(0,949)	0,004	90,600
	0,019	0,053		0,415	0,007	6,101
Ghana	(0,205)	2,113	(0,460)	0,101		31,752

	Terms of Trade	Government	Openess	Interest Rate	Trend	Constant
	0,034	0,075	0,194	0,372		9,149
Kenya	0,065	0,378	(4,243)	(1,059)	0,161	75,200
	0,038	0,055	0,248	0,163	0,009	3,809
Liberia	(0,049)	0,411	(1,024)			97,235
	0,062	0,058	0,152			9,998
Madagascar	(0,292)	2,403	7,144	(4,280)		(52,262)
	0,030	0,137	0,717	0,281		16,324
Malawi		1,813	0,396	(0,015)		(1,763)
		0,156	0,298	0,381		12,472
Morocco		0,114	(0,938)	(0,582)	0,097	69,382
		0,074	0,181	0,124	0,003	2,770
Niger	(0,433)	(0,726)		(0,888)	0,316	84,161
	0,056	0,112		0,512	0,013	4,367
Nigeria	(0,237)	0,355	0,302	0,318		78,618
	0,038	0,068	0,589	0,688		3,566
Senegal	(0,840)	0,044	(6,611)		0,152	269,341
	0,112	0,054	0,365		0,006	12,421
Sierra Leone	(0,664)	(0,526)	11,779			96,645
	0,360	0,333	2,972			48,323
South Africa		0,434	3,113	(2,207)		12,679
		0,096	0,161	0,177		7,149
Sudan		3,461	(1,584)	(8,014)		235,321
		0,726	0,906	1,959		24,831
Togo	(0,102)	(0,563)		(0,639)		160,030
	0,035	0,056		0,350		4,845
Tunisia		0,243			(0,080)	105,233
		0,041			0,004	3,476
Zimbabwe		1,144	1,164	(2,110)		29,301
		0,081	0,247	0,416		9,990
Rwanda	0,115	4,773	5,971			(189,385)
	0,079	0,290	0,622			23,234
Ivory Coast	(0,031)	1,209	(2,200)	(2,299)		80,454
	0,012	0,065	0,279	0,266		4,906

Table 2: Markov Switching Model: Estimation Results Summary
Dependent variable: Exchange Rate Misalignment

$$m_t - \mu(s_t) = \emptyset\left(m_{t-1} - \mu(s_{t-1})\right) + \sigma(s_t)\varepsilon_t$$

$$p_{ii} = \frac{exp(\beta_i)}{1+exp(\beta_i)}.$$

Countries	Mean		Constant part of probability		Standard Deviation		Auto-regressive Factor	Likelihood Ratio Statistic	Maximum Likelihood Function Value (MSM)
	$\mu(1)$	$\mu(2)$	β_1	β_2	$\sigma(1)$	$\sigma(2)$	α		
Austria	2,470	(1,809)	3,794	3,844	0,898	-	0,904	43,04	217,56
	15,60	(3,20)	8,82	8,62	38,91	-	57,12		
Belgium	0,958	(3,179)	4,784	4,101	0,621	-	0,979	60,28	38,83
(*)	0,71	NaN	7,95	6,48	30,49	-	NaN		
Denmark	(0,323)	(3,803)	4,297	2,970	1,040	0,775	0,985	30,12	189,76
	11,59	(1,42)	9,33	6,42	14,23	(3,28)	97,01		
Finland	9,747	(5,570)	4,177	5,380	1,531	-	0,985	91,98	450,59
	54,12	(1,34)	5,54	7,36	32,02	-	NaN		
France	0,959	(3,429)	3,968	3,023	1,009	-	0,968	36,84	288,94
	11,71	(2,26)	8,87	6,30	27,67	-	83,10		
Germany	0,581	(5,557)	5,415	2,541	1,050	-	0,992	43,75	269,86
	13,23	(1,15)	10,41	3,63	46,07	-	NaN		
Greece	1,877	(5,912)	5,323	4,059	1,116	-	0,959	53,05	305,73
	4,17	(2,79)	5,19	5,08	24,92	-	56,45		
Ireland	0,287	(4,076)	3,827	1,109	1,064	-	0,969	44,36	318,14
	10,00	(2,47)	9,89	1,18	25,98	-	83,20		
Italy	6,201	(0,342)	1,253	4,421	1,105	-	0,963	68,36	302,43
	14,81	(0,24)	2,19	9,70	29,39	-	73,67		
Netherlands	3,006	(0,520)	0,543	4,578	0,750	-	0,959	42,25	116,54
	11,81	(0,60)	0,80	9,52	29,58	-	66,23		
Norway	2,306	(1,685)	3,536	3,432	1,038	-	0,969	25,04	273,94
	9,62	(0,96)	7,15	5,11	24,77	-	75,39		
Portugal	1,267	(4,141)	4,117	2,543	1,319	-	0,956	31,55	391,60
	11,31	(2,75)	9,29	4,80	27,91	-	66,99		

Countries	Mean		Constant part of probability		Standard Deviation		Auto-regressive Factor	Likelihood Ratio Statistic	Maximum Likelihood Function Value (MSM)
	$\mu(1)$	$\mu(2)$	β_1	β_2	$\sigma(1)$	$\sigma(2)$	α		
Spain	2,956	(3,510)	3,643	3,562	1,401	-	0,928	39,06	440,72
	16,15	(2,88)	8,29	10,88	28,42	-	40,35		
Sweden	5,659	(4,730)	4,260	4,719	1,350	-	0,990	25,46	401,68
	17,31	(0,73)	6,80	7,86	30,61	-	NaN		
Switzerland	2,322	(1,513)	3,906	1,839	1,179	-	0,984	11,24	343,43
	8,23	(0,40)	7,63	3,24	24,57	-	94,91		
United Kingdon	5,507	(4,591)	4,346	4,672	1,653	-	0,958	44,08	495,76
	12,91	(2,28)	6,73	7,61	30,25	-	66,77		
Argentina	44,264	(41,761)	5,733	6,242	5,758	-	0,990	68,35	993,49
	15,43	(1,47)	4,79	6,02	33,41	-	NaN		
Bolivia	4,405	(58,201)	4,630	3,427	6,367	-	0,951	64,06	537,93
(*)	0,48	NaN	6,36	3,97	20,95	-	49,87		
Brazil	11,714	(9,869)	3,113	3,591	4,883	-	0,959	51,59	1.035,08
	14,03	(1,66)	7,76	8,55	27,82	-	68,56		
Canada	1,223	(1,063)	2,877	2,507	0,800	-	0,975	(2,89)	209,94
	9,31	(0,70)	5,89	5,88	18,74	-	89,83		
Chile	6,436	(46,133)	5,256	4,705	3,507	-	0,990	161,47	838,13
	25,57	(2,71)	7,10	5,40	30,32	-	NaN		
Colombia	2,784	(11,080)	4,824	3,582	1,255	-	0,985	152,31	371,05
	26,74	(2,87)	8,20	6,46	30,63	-	NaN		
Costa Rica	18,223	(0,699)	(0,004)	5,030	2,388	-	0,953	105,48	662,18
	18,39	(0,29)	-	8,68	30,27	-	66,54		
Ecuador	8,877	(9,285)	4,204	3,980	2,430	-	0,972	35,15	351,89
	14,84	(1,66)	5,64	6,43	21,71	-	57,86		
El Salvador	15,805	(8,158)	4,537	5,311	2,513	2,516	0,983	81,87	682,60
	15,30	(1,24)	5,53	7,25	25,40	0,01	NaN		
Guatemala	165,401	107,813	5,907	6,280	2,186	-	1,001	197,05	606,59
	26,92	0,28	4,60	5,42	30,83	-	NaN		
Haiti	21,538	(4,040)	2,368	5,201	3,302	-	0,973	70,69	659,86
	15,24	(0,65)	3,28	7,26	27,03	-	72,98		
Honduras									

Countries	Mean		Constant part of probability		Standard Deviation		Auto-regressive Factor	Likelihood Ratio Statistic	Maximum Likelihood Function Value (MSM)
	$\mu(1)$	$\mu(2)$	β_1	β_2	$\sigma(1)$	$\sigma(2)$	α		
	73,347	18,275	5,702	6,320	2,924	-	1,007	118,47	742,37
	19,27	0,64	4,16	5,76	32,09	-	NaN		
Jamaica	12,037	(10,823)	4,446	6,076	1,875	4,450	0,980	143,93	626,84
	11,98	(1,78)	5,07	6,04	26,66	7,81	89,15		
Mexico	12,113	(12,716)	1,387	5,018	2,186	18,050	0,980	280,97	655,58
	19,65	(1,64)	2,16	8,71	30,04	4,84	NaN		
Paraguay	4,062	(3,224)	1,944	4,133	2,275	8,957	0,964	159,17	732,51
	4,58	(1,00)	3,40	9,36	26,64	5,61	73,05		
Peru	71,672	(5,004)	1,241	4,616	13,153	-	0,947	65,00	1.266,30
	12,01	(0,42)	2,05	8,69	27,09	-	58,86		
Trinidad Tobago	(5,817)	(20,030)	3,851	4,420	2,030	-	0,995	39,06	600,28
	18,40	(0,75)	7,13	8,65	29,94	-	NaN		
United States	3,637	(1,323)	1,762	3,739	1,691	-	0,981	25,46	530,27
	8,86	(0,32)	3,74	8,73	25,76	-	NaN		
Uruguay	25,193	(13,363)	2,979	3,844	5,163	-	0,958	11,24	913,19
	25,04	(2,15)	7,23	9,30	28,25	-	65,42		
Venezuela	18,769	(6,563)	2,835	4,120	3,659	-	0,946	44,08	558,71
	17,03	(1,47)	4,37	8,02	23,66	-	40,81		
Australia	6,105	(0,583)	1,104	3,807	1,647	-	0,953	42,77	497,70
	13,61	(0,35)	2,33	10,50	26,99	-	62,54		
Indonesia	(2,054)	(10,752)	3,804	3,736	1,887	-	0,994	34,26	433,99
	8,46	(0,62)	6,62	5,76	23,37	-	NaN		
New Zealand	(8,938)	(22,249)	4,125	3,908	1,987	-	0,994	90,83	576,75
	13,45	(0,98)	8,70	6,34	29,69	-	NaN		
Papua New Guinea	2,705	(2,337)	2,750	3,104	1,203	-	0,956	30,20	276,90
	15,93	(1,47)	7,33	7,81	24,79	-	57,61		
Bahrain	14,019	(1,004)	2,644	5,352	1,248	-	0,963	4,57	164,51
	16,74	(0,42)	2,70	5,22	NaN	-	50,23		
Bangladesh	6,399	(13,191)	1,920	5,665	2,263	-	0,761	(94,86)	541,51
	19,59	NaN	1,92	5,66	2,26	-	0,76		
Hong Kong	(27,934)	(36,302)	4,768	4,557	1,630	-	0,997	5,80	334,50

Countries	Mean		Constant part of probability		Standard Deviation		Auto-regressive Factor	Likelihood Ratio Statistic	Maximum Likelihood Function Value (MSM)
	$\mu(1)$	$\mu(2)$	β_1	β_2	$\sigma(1)$	$\sigma(2)$	α		
	8,38	(0,34)	6,11	5,21	24,78	-	96,88		
India	11,648	(2,301)	3,112	4,562	1,956	-	0,964	49,99	283,22
	13,74	(0,62)	4,58	6,25	20,68	-	50,93		
Israel	10,461	(1,953)	2,638	4,373	2,207	-	0,962	55,26	513,87
	14,04	(0,64)	4,85	8,53	26,47	-	65,91		
Japan	2,356	(3,281)	3,744	2,637	1,763	-	0,976	12,56	509,50
	8,77	(0,91)	8,26	4,64	25,22	-	89,55		
Jordan	0,118	(3,984)	3,738	(0,177)	1,141	-	0,938	16,90	172,04
	9,93	(3,05)	8,03	(0,25)	20,52	-	40,33		
Korea	21,590	(4,661)	3,932	4,726	2,611	-	0,972	119,86	649,22
	22,08	(1,02)	6,19	7,96	29,28	-	85,15		
Kuwait	0,279	(4,823)	4,174	2,097	1,718	1,139	0,935	18,12	175,59
	8,44	(3,40)	7,17	3,17	7,02	(2,29)	38,81		
Malaysia	(2,424)	(6,082)	3,942	2,758	0,797	-	0,990	39,77	176,30
	14,86	(1,30)	10,17	6,19	29,53	-	NaN		
Nepal	5,533	(1,116)	1,635	3,878	2,079	-	0,941	0,40	384,44
	8,06	(0,53)	2,37	7,79	22,39	-	45,96		
Pakistan	2,483	(0,579)	1,721	2,903	1,392	-	0,894	(0,74)	218,98
	5,49	(0,56)	2,26	3,83	12,42	-	27,52		
Philiphines	17,954	(2,129)	3,015	4,631	2,960	-	0,954	36,79	772,61
	16,80	(0,69)	4,84	9,18	30,24	-	69,89		
Saudi Arabia	(1,620)	(6,499)	4,361	1,653	1,294	-	0,987	(4,71)	191,50
	7,20	(0,93)	6,59	2,20	19,65	-	88,81		
Singapore	1,053	(1,488)	4,857	4,173	0,922	-	0,952	(0,02)	86,28
	1,76	(0,57)	4,19	2,59	16,97	-	37,79		
Sri Lanka	14,405	(10,407)	5,863	5,083	1,896	-	0,986	50,24	531,93
	31,75	(1,92)	6,18	6,21	36,65	-	NaN		
Thailand	1,855	(3,704)	3,527	3,565	1,323	-	0,964	27,04	402,56
	11,87	(1,68)	6,25	5,98	27,09	-	62,52		
Turkey	6,089	(12,509)	4,017	4,103	2,867	-	0,987	54,24	588,11

Countries	Mean		Constant part of probability		Standard Deviation		Auto-regressive Factor	Likelihood Ratio Statistic	Maximum Likelihood Function Value (MSM)
	$\mu(1)$	$\mu(2)$	β_1	β_2	$\sigma(1)$	$\sigma(2)$	α		
	15,12	(0,99)	6,32	7,70	26,54	-	92,16		
Algeria	15,101	(11,900)	3,331	4,432	3,545	-	0,981	69,19	553,17
	16,79	(1,03)	5,08	7,54	24,49	-	75,05		
Burkina Faso	52,445	(0,162)	(13,027)	5,994	4,270	-	0,945	99,15	791,53
	17,15	(0,04)	(9,96)	5,95	28,23	-	58,18		
Burundi	4,724	(4,263)	3,177	3,450	2,802	1,894	0,975	16,19	446,51
	18,30	(1,03)	10,16	17,20	56,51	(7,39)	93,27		
Cameroon	53,602	1,324	(10,555)	5,913	3,435	-	0,974	82,44	704,96
	21,22	0,20	(1,74)	5,95	27,26	-	79,77		
Central Africa	0,161	(5,070)	3,422	4,039	(0,872)	(1,190)	0,980	600,01	205,74
	14,34	(1,87)	7,09	7,78	NaN	(2,53)	98,16		
Zaire	29,988	(8,967)	4,225	4,107	3,613	7,067	0,966	102,40	845,74
	21,01	(1,35)	6,96	7,92	20,74	8,24	71,98		
Congo	46,880	(0,245)	(15,706)	6,006	3,223	-	0,901	124,15	686,81
	20,21	(0,16)	(0,01)	6,13	29,72	-	42,27		
Egypt	41,089	(10,911)	3,865	4,558	5,002	-	0,971	144,47	1.017,00
	25,10	(1,38)	6,76	8,90	30,39	-	92,02		
Ethiopia	30,214	(64,648)	5,428	6,161	3,866	-	0,996	168,80	739,21
	24,39	(0,73)	3,81	5,51	28,03	-	NaN		
Gabon	83,807	(12,333)	3,864	6,027	2,643	-	0,989	269,57	562,09
	34,96	(0,63)	1,66	5,85	27,46	-	62,98		
Ghana	7,116	(20,700)	3,770	4,330	3,320	-	0,988	18,12	765,44
	22,15	(1,26)	7,09	8,35	29,36	-	NaN		
Kenya	0,887	(11,593)	4,794	1,394	2,567	-	0,911	39,77	558,72
	10,22	(6,05)	8,06	2,09	26,16	-	41,07		
Liberia	2,942	(0,912)	2,351	3,221	1,473	2,179	0,951	0,40	203,37
	4,20	(0,30)	2,18	4,63	10,24	2,40	37,75		
Madagascar	26,861	(8,460)	3,864	5,293	2,848	-	0,983	(0,74)	665,74
	21,20	(1,00)	4,45	7,42	28,93	-	NaN		
Malawi	32,006	(13,097)	4,967	5,598	5,709	-	0,968	36,79	515,65
	7,67	(1,06)	3,56	4,97	21,35	-	55,24		

Countries	Mean		Constant part of probability		Standard Deviation		Auto-regressive Factor	Likelihood Ratio Statistic	Maximum Likelihood Function Value (MSM)
	$\mu(1)$	$\mu(2)$	β_1	β_2	$\sigma(1)$	$\sigma(2)$	α		
Morocco	1,304	(6,148)	4,136	5,217	1,001	-	0,992	33,89	256,95
	14,86	(0,95)	6,41	7,20	30,66	-	NaN		
Niger	65,839	(8,983)	1,883	5,895	4,710	-	1,111	(0,02)	767,41
	74,79	(8,21)	1,94	5,90	8,62	-	91,71		
Nigeria	29,865	(8,962)	4,246	5,472	4,054	-	0,989	50,24	828,80
(*)	1,29	NaN	0,02	6,97	34,78	-	NaN		
Senegal	115,507	31,178	5,269	6,102	2,917	-	1,006	27,04	590,11
	28,93	0,65	3,52	5,48	27,99	-	NaN		
Sierra Leone	2,990	(46,582)	4,018	2,841	7,923	-	0,921	54,24	327,60
	10,44	(6,49)	9,52	3,78	15,83	-	31,86		
South Africa	16,720	0,092	1,286	4,730	1,922	-	0,962	69,19	568,83
	25,61	0,05	1,99	11,43	31,29	-	78,08		
Sudan	64,618	(6,699)	1,256	3,341	15,207	-	0,893	17,82	318,41
	9,71	(0,44)	1,13	5,59	13,47	-	18,64		
Togo	297,748	218,287	5,241	6,034	2,474	-	1,001	222,91	495,20
	31,72	0,12	3,61	5,45	26,17	-	NaN		
Tunisia	1,861	(0,907)	3,537	4,534	1,850	-	0,650	(47,06)	106,75
	2,79	(0,95)	3,54	4,53	2,13	-	0,79		
Zimbabwe	31,525	10,481	0,785	4,087	4,415	-	0,981	37,05	524,77
	11,28	0,66	1,12	8,66	22,13	-	53,27		
Rwanda	149,542	(1,526)	1,369	5,612	9,064	-	0,908	619,23	752,81
	22,75	(0,25)	1,24	5,67	23,25	-	34,78		
Ivory Coast	119,985	35,884	5,365	6,332	2,783	-	1,004	231,13	719,16
	29,91	0,61	3,52	5,78	30,52	-	NaN		

Table 3: Markov Switching Model: Estimation Results Summary
Dependent variable: Exchange Rate Misalignment

Countries	Transition Probabilities		Goldfajn e Valdes (1999) Methodology		Markov Switching Model	
			Number/Average Duration		Number/Average Duration	
	p11	p22	Depreciations	Appreciations	Depreciations	Appreciations
Austria	0,9780	0,9790	-	-	7	8
					24	25
Belgium	0,9917	0,9837	-	-	3	2
					107	64
Denmark	0,9866	0,9512	-	-	4	2
					87	34
Finland	0,9849	0,9954	2	-	1	-
			30		374	
France	0,9814	0,9536	-	-	7	5
					46	17
Germany	0,9956	0,9270	1	-	3	3
			44		109	27
Greece	0,9951	0,9830	-	1	2	2
				16	175	51
Ireland	0,9787	0,7519	-	-	8	3
					51	4
Italy	0,7779	0,9881	1	-	4	4
			4		3	106
Netherlands	0,6325	0,9898	-	-	1	4
					6	97
Norway	0,9717	0,9687	-	-	8	4
					24	25
Portugal	0,9840	0,9271	-	-	6	4
					55	12
Spain	0,9745	0,9724	-	-	4	3
					92	18
Sweden	0,9861	0,9912	1	2	-	-
			112	17		
Switzerland	0,9803	0,8629	-	1	10	5
				15	33	6
United Kingdon	0,9872	0,9907	1	-	2	7
			5		91	30
Argentina	0,9968	0,9981	6	7	2	5
			24	16	95	17
Bolivia	0,9903	0,9685	5	5	1	1
			5	6	209	10
Brazil	0,9574	0,9732	6	3	6	4
			19	24	30	34
Canada	0,9467	0,9247	-	-	16	9
					13	8
Chile	0,9948	0,9910	4	3	4	-
			8	14	104	

Countries	Transition Probabilities		Goldfajn e Valdes (1999) Methodology		Markov Switching Model	
			Number/Average Duration		Number/Average Duration	
	p11	p22	Depreciations	Appreciations	Depreciations	Appreciations
Colombia	0,9920	0,9729	3	2	2	1
			40	54	189	86
Costa Rica	0,4990	0,9935	3	2	4	4
			22	9	10	103
Ecuador	0,9853	0,9817	4	2	1	-
			9	30	108	
El Salvador	0,9894	0,9951	2	3	2	-
			56	25	110	
Guatemala	0,9973	0,9981	2	2	1	4
			36	20	150	22
Haiti	0,9144	0,9945	2	3	2	2
			32	19	11	176
Honduras	0,9967	0,9982	1	3	1	2
			61	27	105	176
Jamaica	0,9884	0,9977	5	3	7	6
			19	18	22	45
Mexico	0,8001	0,9934	5	3	5	7
			23	20	12	55
Paraguay	0,8748	0,9842	6	6	5	9
			15	17	3	43
Peru	0,7757	0,9902	9	7	3	5
			12	13	14	66
Trinidad Tobago	0,9792	0,9881	2	3	2	1
			58	15	129	113
United States	0,8535	0,9768	3	2	5	11
			14	29	5	33
Uruguay	0,9516	0,9790	11	5	5	5
			12	22	38	36
Venezuela	0,9445	0,9840	5	4	4	1
			8	7	38	123
Australia	0,7511	0,9783	1	-	8	8
			23		4	46
Indonesia	0,9782	0,9767	1	3	1	-
			113	42	205	
New Zealand	0,9841	0,9803	1	2	3	5
			11	22	65	30
Papua New Guinea	0,9399	0,9571	1	-	5	7
			9		24	16
Bahrain	0,9336	0,9953	1	-	-	1
			17			197
Bangladesh	0,8721	0,9965	1	2	1	1
			10	11	267	22
Hong Kong	0,9916	0,9896	2	2	1	1

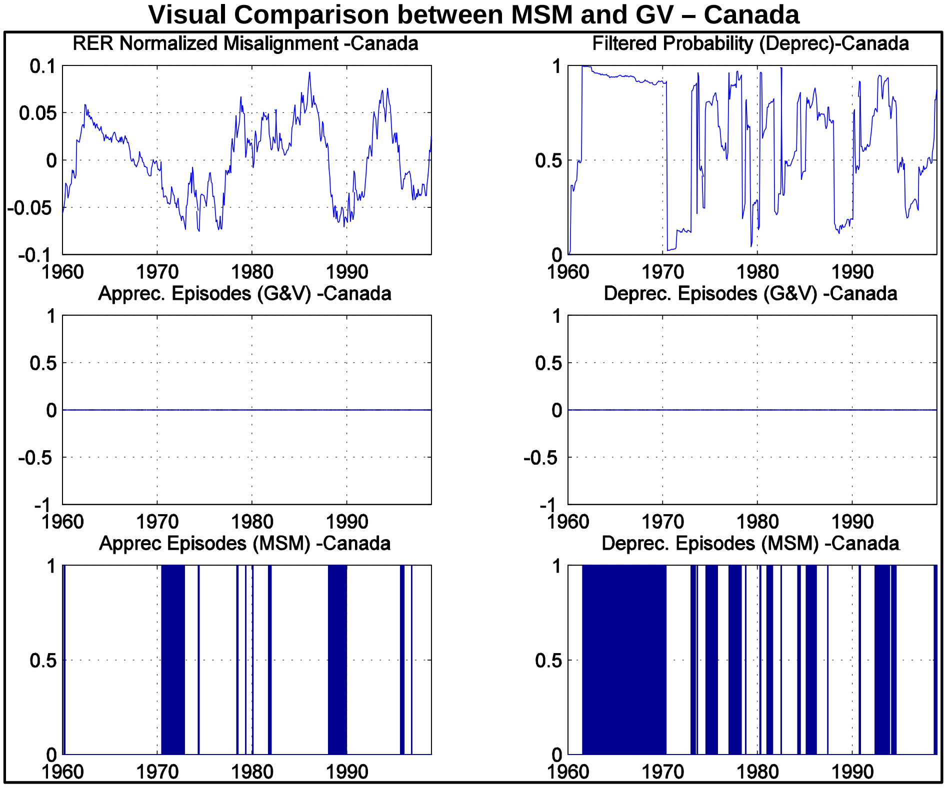
Countries	Transition Probabilities		Goldfajn e Valdes (1999) Methodology		Markov Switching Model	
			Number/Average Duration		Number/Average Duration	
	p11	p22	Depreciations	Appreciations	Depreciations	Appreciations
			31	39	192	115
India	0,9574	0,9897	1	-	1	1
			14		55	168
Israel	0,9333	0,9875	2	2	5	4
			19	10	19	60
Japan	0,9769	0,9332	4	2	9	6
			8	15	27	12
Jordan	0,9768	0,4559	-	-	9	2
					22	2
Korea	0,9808	0,9912	3	1	2	1
			19	11	193	18
Kuwait	0,9848	0,8906	-	-	4	2
					45	13
Malaysia	0,9810	0,9403	1	1	4	4
			14	5	87	14
Nepal	0,8369	0,9797	2	4	3	8
			9	8	9	25
Pakistan	0,8482	0,9480	-	-	3	15
					2	8
Philiphines	0,9533	0,9903	4	1	2	2
			19	32	106	108
Saudi Arabia	0,9874	0,8392	1	1	2	1
			19	21	105	13
Singapore	0,9923	0,9848	-	-	5	-
					16	
Sri Lanka	0,9972	0,9938	3	2	1	-
			64	80	241	
Thailand	0,9714	0,9725	2	-	4	8
			22		48	15
Turkey	0,9823	0,9837	3	5	4	-
			35	11	46	
Algeria	0,9655	0,9883	2	1	2	2
			17	7	44	96
Burkina Faso	0,0000	0,9975	5	3	1	1
			18	15	3	396
Burundi	0,9600	0,9692	4	4	5	5
			5	16	30	20
Cameroon	0,0000	0,9973	1	1	1	1
			60	77	4	364
Central Africa	0,9684	0,9827	2	-	3	4
			13		40	53
Zaire	0,9856	0,9838	10	5	4	4
			20	18	55	38

Countries	Transition Probabilities		Goldfajn e Valdes (1999) Methodology		Markov Switching Model	
			Number/Average Duration		Number/Average Duration	
	p11	p22	Depreciations	Appreciations	Depreciations	Appreciations
Congo	0,0000	0,9975	2	1	1	1
			11	3	2	401
Egypt	0,9795	0,9896	5	2	1	-
			38	62	239	
Ethiopia	0,9956	0,9979	3	2	1	4
			28	40	74	22
Gabon	0,9795	0,9976	2	2	1	-
			12	27	5	
Ghana	0,9775	0,9870	9	7	2	3
			12	17	118	54
Kenya	0,9918	0,8012	3	3	3	1
			5	5	119	6
Liberia	0,9130	0,9616	-	-	3	6
					3	14
Madagascar	0,9795	0,9950	3	4	1	-
			34	37	137	
Malawi	0,9931	0,9963	4	4	1	5
			8	8	50	26
Morocco	0,9843	0,9946	1	1	1	6
			94	10	141	50
Niger	0,8680	0,9973	4	2	1	-
			25	58	59	
Nigeria	0,9859	0,9958	2	4	2	2
			76	36	48	176
Senegal	0,9949	0,9978	2	1	1	-
			19	27	59	
Sierra Leone	0,9823	0,9448	4	3	1	1
			10	14	96	21
South Africa	0,7835	0,9913	4	1	4	4
			6	14	4	109
Sudan	0,7784	0,9658	4	3	4	2
			7	5	10	18
Togo	0,9947	0,9976	1	4	1	2
			60	15	59	103
Tunisia	0,9717	0,9894	-	-	1	2
					21	43
Zimbabwe	0,6868	0,9835	3	2	4	3
			8	12	2	78
Rwanda	0,7972	0,9964	5	5	1	1
			14	20	4	268
Ivory Coast	0,9953	0,9982	4	2	1	2
			16	10	59	191
China	0,0000	0,0000	-	-	-	-

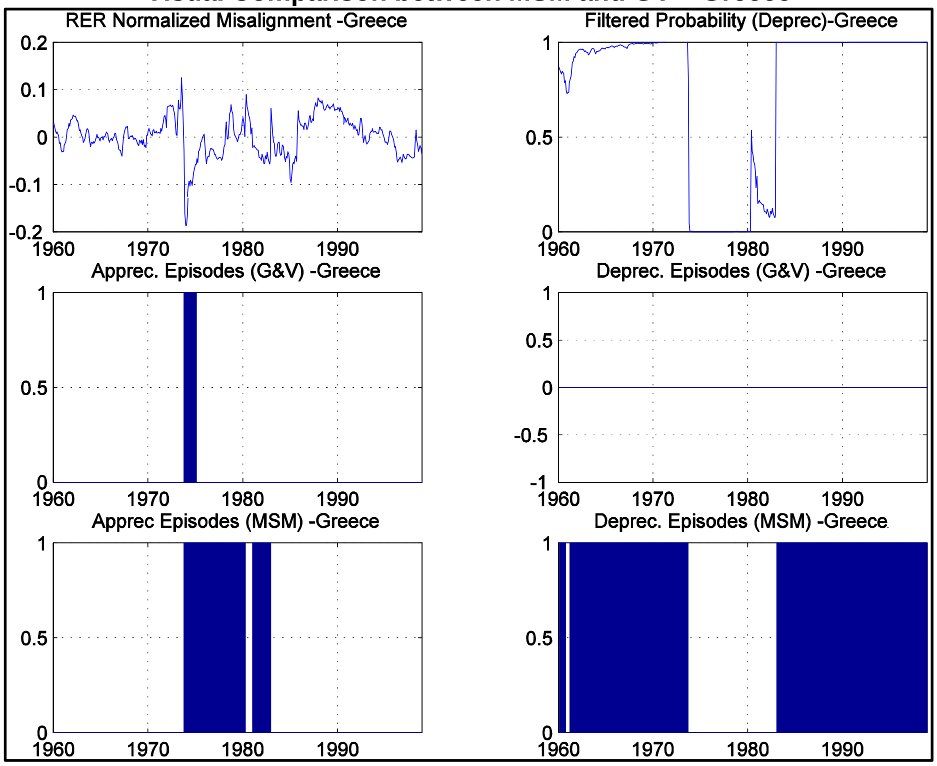
Countries	Transition Probabilities		Goldfajn e Valdes (1999) Methodology		Markov Switching Model	
			Number/Average Duration		Number/Average Duration	
	p11	p22	Depreciations	Appreciations	Depreciations	Appreciations
Hungary	0,0000	0,0000	-	-	-	-
Iran	0,0000	0,0000	2 55	3 41	-	-
Poland	0,0000	0,0000	-	-	-	-
Romania	0,0000	0,0000	-	-	-	-
Somalia	0,0000	0,0000	-	-	-	-
Syria	0,0000	0,0000	-	-	-	-
Zambia	0,0000	0,0000	4 11	6 15	-	-

RER Misalignments Comparisons

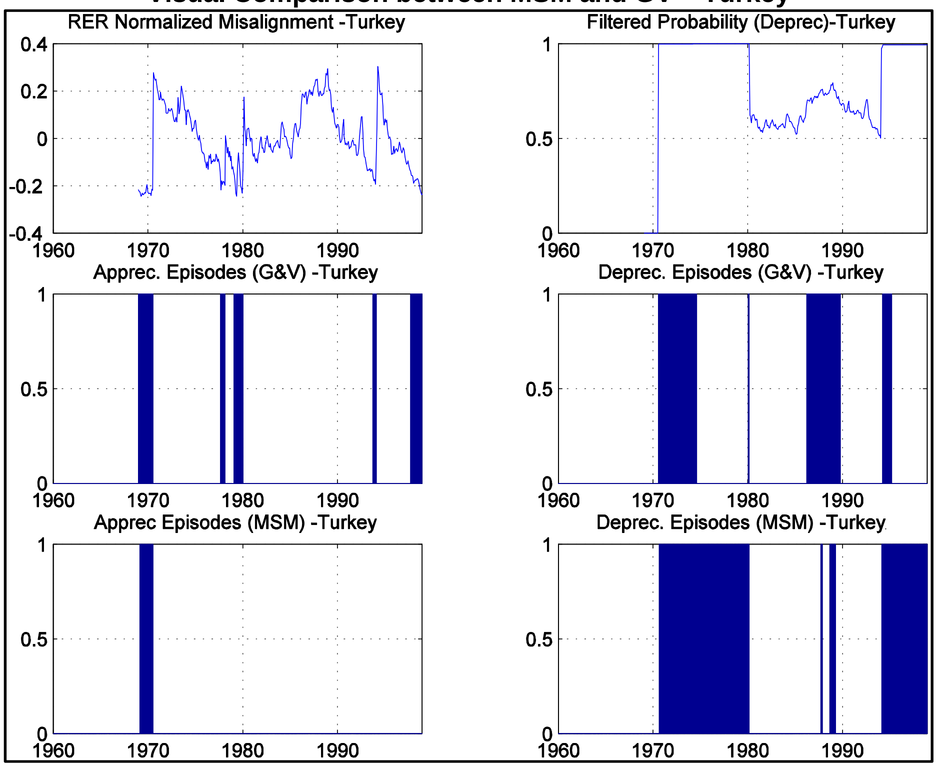
Visual Comparison between MSM and GV – Canada



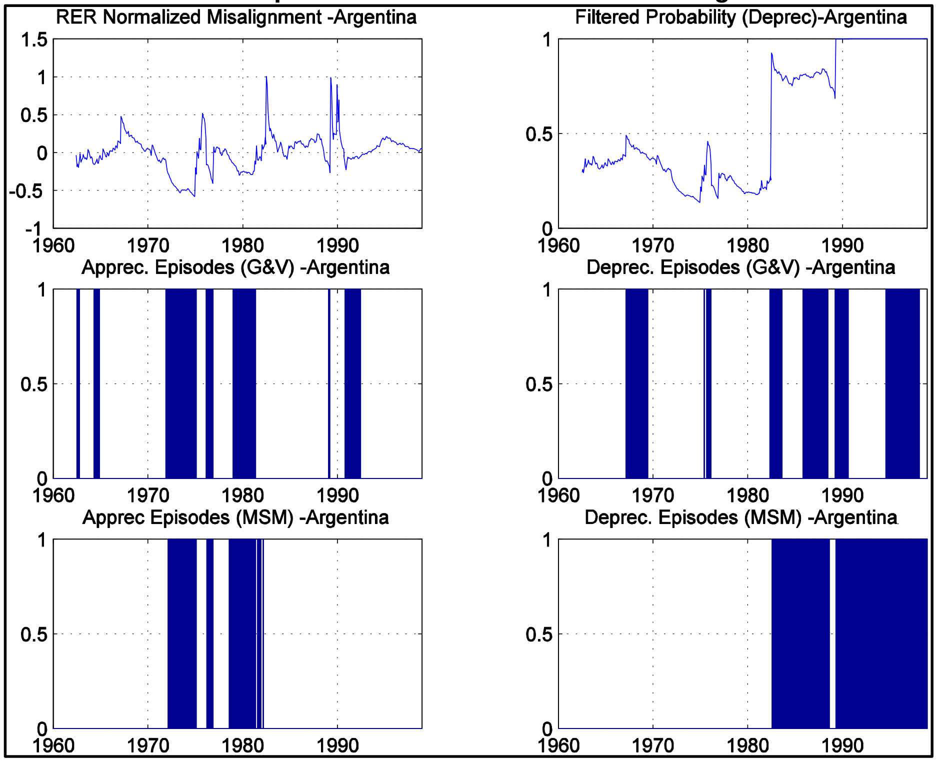
Visual Comparison between MSM and GV – Greece



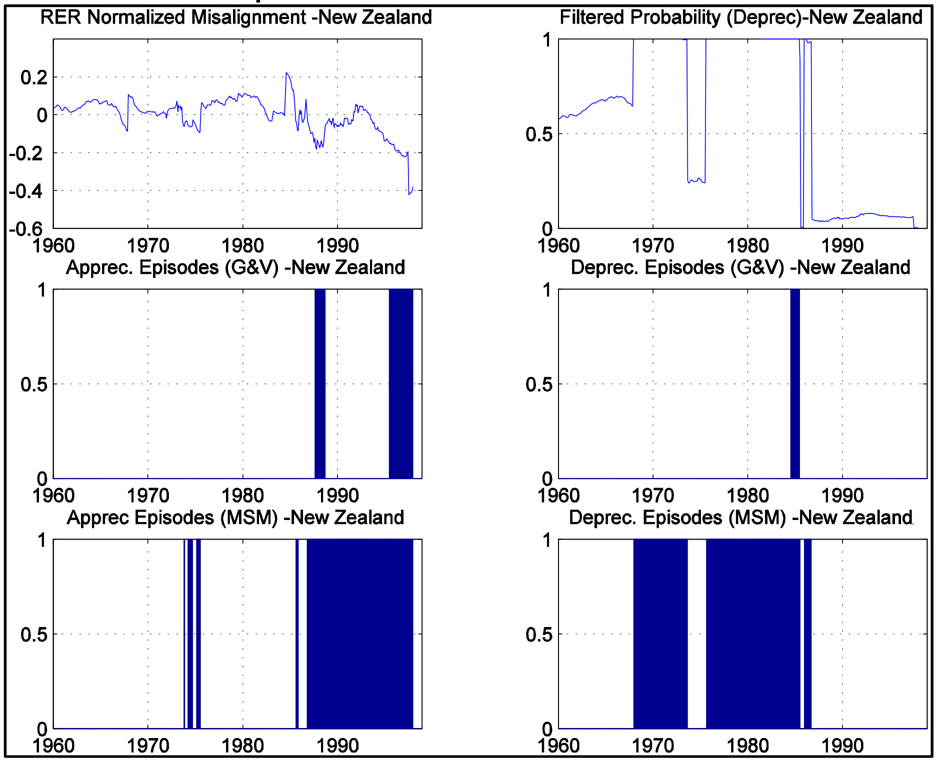
Visual Comparison between MSM and GV – Turkey



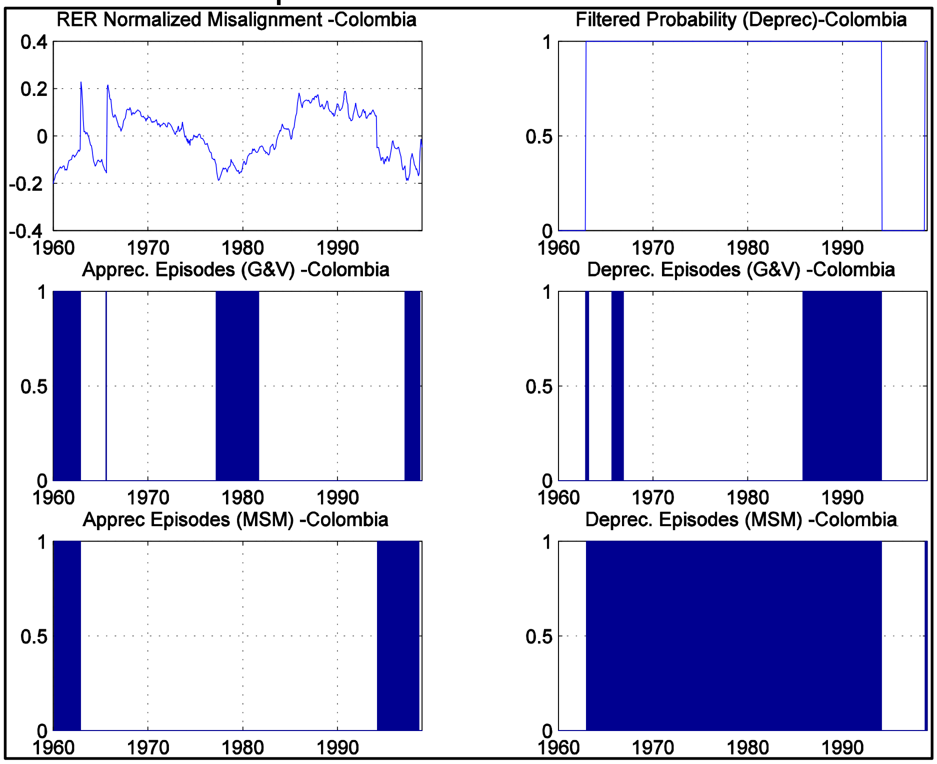
Visual Comparison between MSM and GV – Argentina



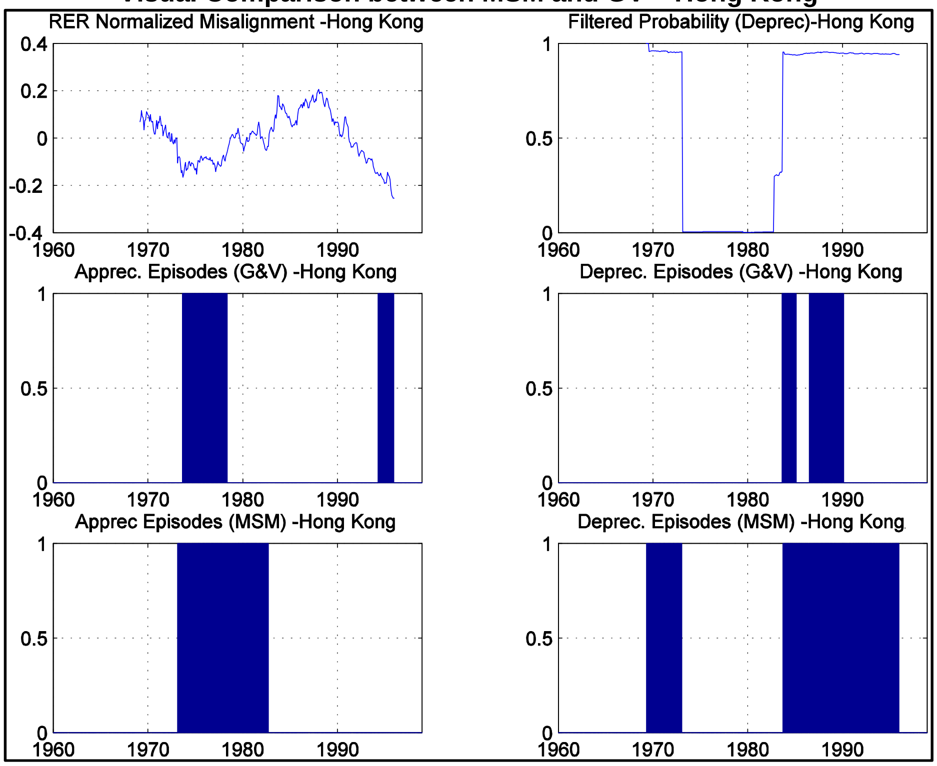
Visual Comparison between MSM and GV – New Zealand



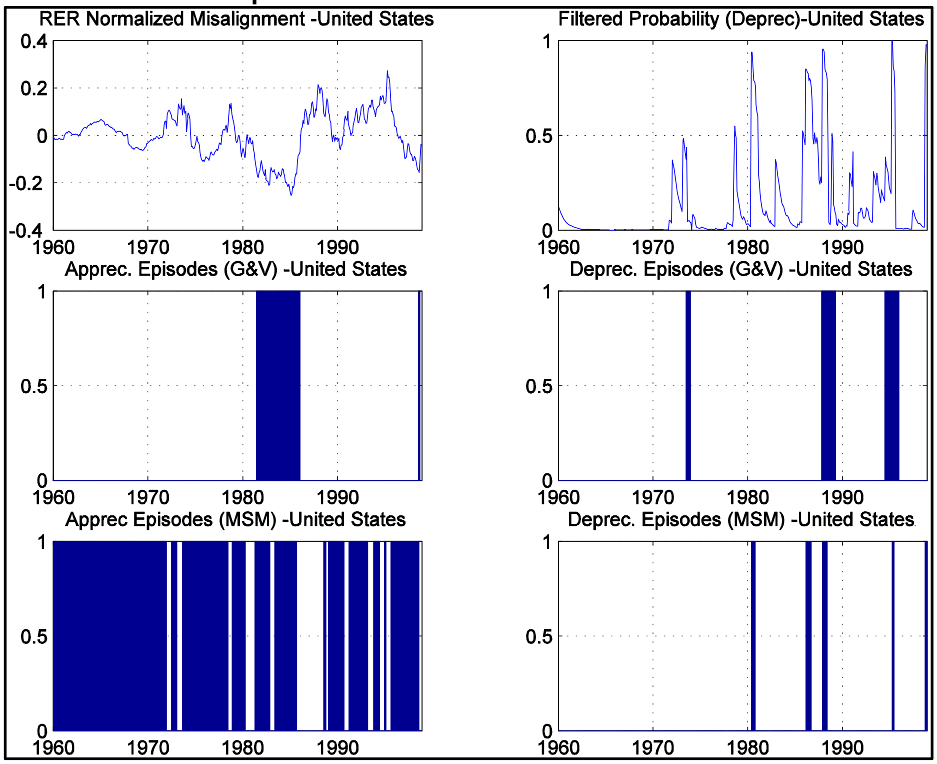
Visual Comparison between MSM and GV – Colombia



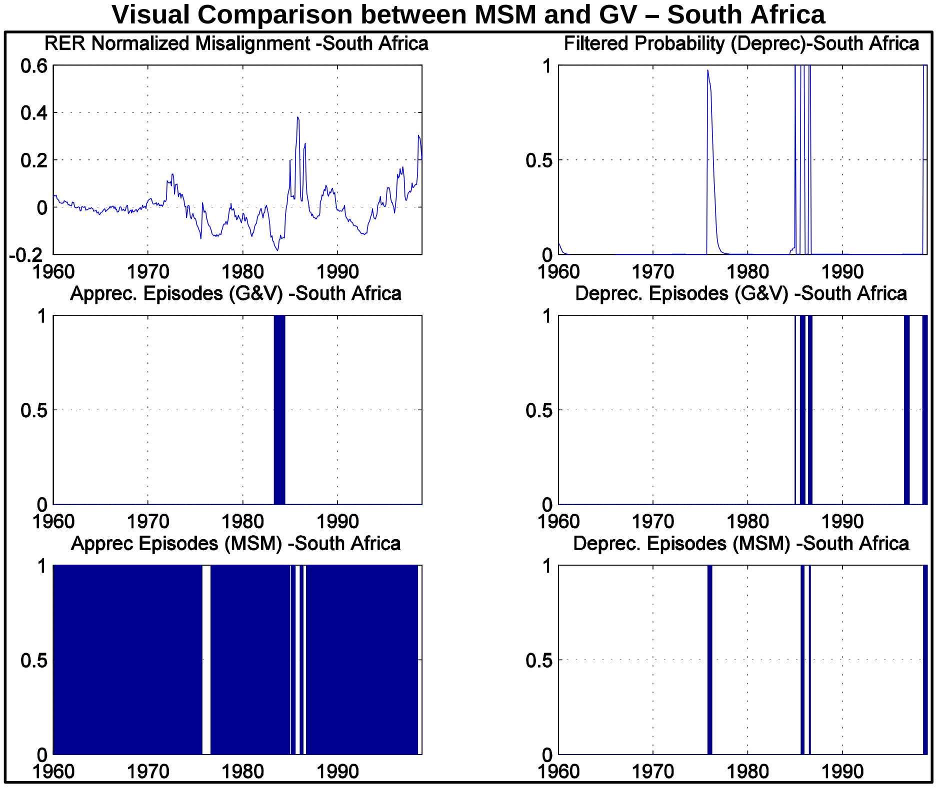
Visual Comparison between MSM and GV – Hong Kong



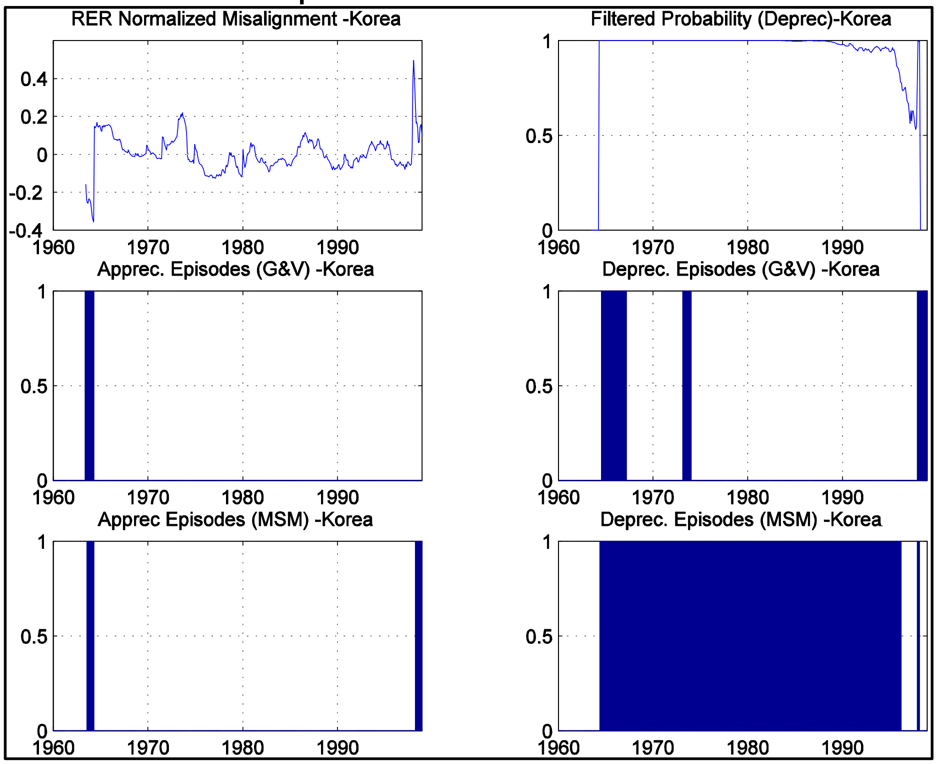
Visual Comparison between MSM and GV – United States



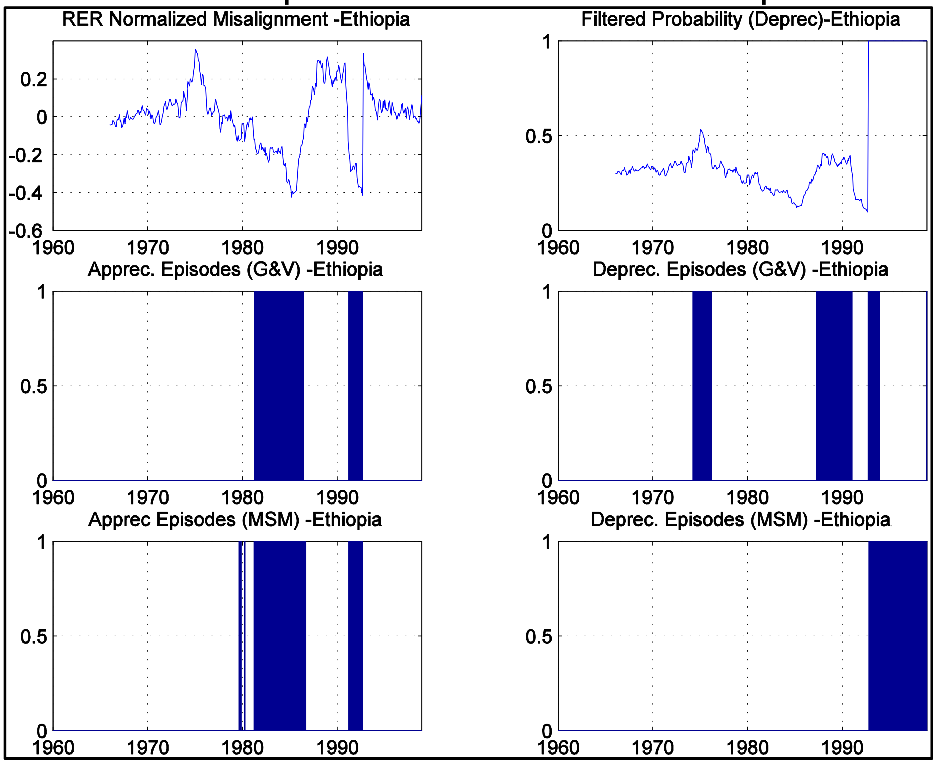
Visual Comparison between MSM and GV – South Africa



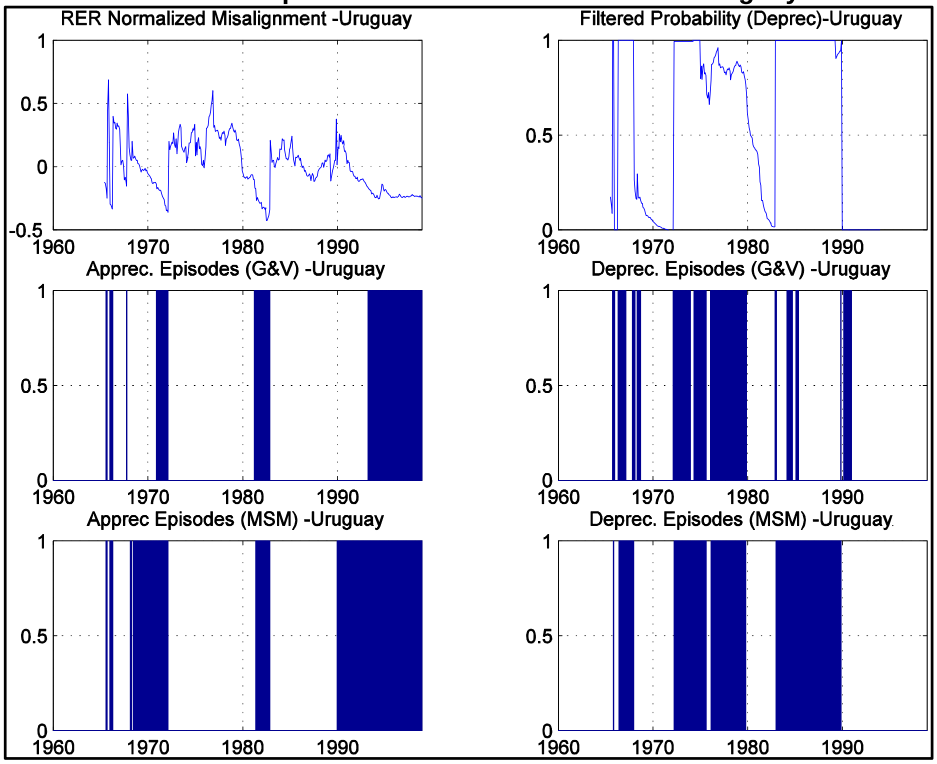
Visual Comparison between MSM and GV – Korea



Visual Comparison between MSM and GV – Ethiopia



Visual Comparison between MSM and GV – Uruguay



Visual Comparison between MSM and GV – Zaire